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Mammalian zoogeography and faunal dynamics in the northwestern region of the United States during the Arikareean (Late Oligocene-Early Miocene)

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MAMMALIAN ZOOGEOGRAPHY AND FAUNAL DYNAMICS

IN THE NORTHWESTERN REGION OF THE UNITED STATES

DURING THE ARIKAREEAN (LATE OLIGOCENE - EARLY MIOCENE)

By

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ABSTRACT

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Mammalian zoogeography and faunal dynamics in the northwest region of the United States during the Arikareean (Late Oligocene-Early Miocene) (105 p.)

Director: Dr. Robert W. Fields

Observational analysis and cluster analysis of mammalian faunal similarity data indicate that three faunal provinces existed in the northwest region of the United States during the Arikareean (Late Oligocene-Early Miocene): the John Day Faunal Province of Oregon, the Intermontane Basin Faunal Province of Montana and Idaho, and the North Platte River-Wounded Knee Faunal Province of Wyoming, Nebraska, and South Dakota. In the Early, and again in the Late Arikareean, dispersal occurred between these faunal provinces. However, each faunal province retained some endemic genera. The John Day Faunal Province and the North Platte River-Wounded Knee Faunal Province retained the most endemic genera. The Intermontane Basin Faunal Province and the North Platte River-Wounded Knee Faunal Province shared the greatest similarity. The Intermontane Basin Faunal Province acted as a filter zone to west-east and east-west dispersing mammals. A slight faunal difference seen within the Intermontane Basin Faunal Province can be attributed to either the continental divide acting as a minor barrier or simply a distance factor. The differences seen in the distributions of Arikareean mammals is most likely attributed to geography.

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INTRODUCTION

Most studies on the distribution patterns of mammals involve recent taxa (Flessa, 1981; Brown and Gibson, 1983). A search of the literature shows that few studies exist on the distribution patterns of extinct mammals. Of these few studies, most are subjective. In other words, they are based on observations seen in the fossil record. Only a few attempts have been made to apply quantitative techniques to these kinds of studies (Simpson, 1960; Flynn, 1986). Clearly, more quantitative analyses and new quantitative techniques are needed in the study of the distribution patterns of extinct mammals to confirm observations seen in the fossil record.

In this paper, I present a new quantitative technique (to zoogeography) in analyzing the distribution patterns of extinct mammals, which was used by Flessa (1981) in the analysis of the distributions of recent mammals. I applied the quantitative technique presented here to a study involving the mammalian zoogeography and faunal dynamics in the northwest region of the United States during the Arikareean (Late Oligocene-Early Miocene). Fields and others (1985) and Tedford and others (in press) note that both provincialism and population dispersal occurred in the northwest region of the United States during the

Arikareean. However, the exact details concerning the provincialism and population dispersal remain to be worked out. This study was undertaken to examine in detail the faunal resemblance, and the extent of provincialism and population dispersal (i.e. faunal dynamics) present in the northwest region of the United States during the Arikareean using observation and quantitative analyses.

METHODS

Faunal lists from several well known Arikareean faunas of the northwest region of the United States were compiled through a literature search (see Table 1) and examination of fossil vertebrate material from the University of California Museum of Paleontology, Berkeley, California, the Burke Memorial Washington State Museum, Seattle, Washington, and the Museum of Paleontology University of Montana, Missoula, Montana. In addition, collecting trips to various Montana localities were conducted in hope of adding taxa to some of the Montana faunal lists.

Only faunas with ten or more genera were used in this study. This was done to avoid distortion of faunal similarity values (discussed below). Analyses were done at the generic level, since most identifications of fossil mammals are reliable at this taxonomic level. Identifications made in the various publications used and on Museum specimens were accepted as being correct. Taxa with tentative identifications (i.e. "cf.," "nr.," "?") were assigned to that particular taxon.

Faunal lists for Early Arikareean faunas are reliable, since there is good locality and stratigraphic control. However, this is not the case for the Late Arikareean. Locality data are very poor and stratigraphic data are either misinterpreted or based on outdated information. This is especially true for the John Day area and eastern Wyoming and western Nebraska. This has created problems when compiling these faunal lists because the exact locality and stratigraphic information necessary is lacking. Although the stratigraphy has recently been worked out, new collections must be made, since the older collections contain fossils with no locality or stratigraphic control. Nevertheless, some information was obtained and composite faunal lists for western Nebraska and the John Day area were compiled.

Early and Late Arikareean faunas were analyzed separately. A total of nine faunas for the Early Arikareean (Fig. 1 and Table 1) and four for the Late Arikareean (Fig. 2 and Table 1) were chosen for analysis. The Early Arikareean faunas used in this study are the John Day fauna (lower) (JD_1), Peterson Creek local fauna (PC), Cabbage Patch local faunas (CP), Tavenner Ranch local fauna (TR), Magpie Creek local fauna (MC), Smith River fauna (SR), Goshen Hole fauna (GH), Wildcat Ridge fauna (WR), and the Wounded Knee fauna (lower) (WK_1). The Late Arikareean faunas used in this study are the John Day fauna (upper) (JD_2), Negro Hollow local fauna (NH), western Nebraska composite fauna (WN), and the Wounded Knee fauna (upper) (WK_2).

Analysis of these data consisted of two parts: observation and quantification. The observational analysis consisted of dividing the northwest into regions of distinct geography and depositional environments. Then, various comparisons were made between the regions, which included endemic genera from each region, genera similar between regions, endemic genera between regions, cosmopolitan genera, and disjunct genera. This information was used to observe any patterns of similarity and/or difference between the regions. A quantitative analysis was then conducted to confirm the results obtained from the observations.

Quantification of the data was achieved by cluster analysis. This involved measuring the faunal similarity between the various faunas using several similarity coefficients (Fig. 3) and forming groups of similar faunas

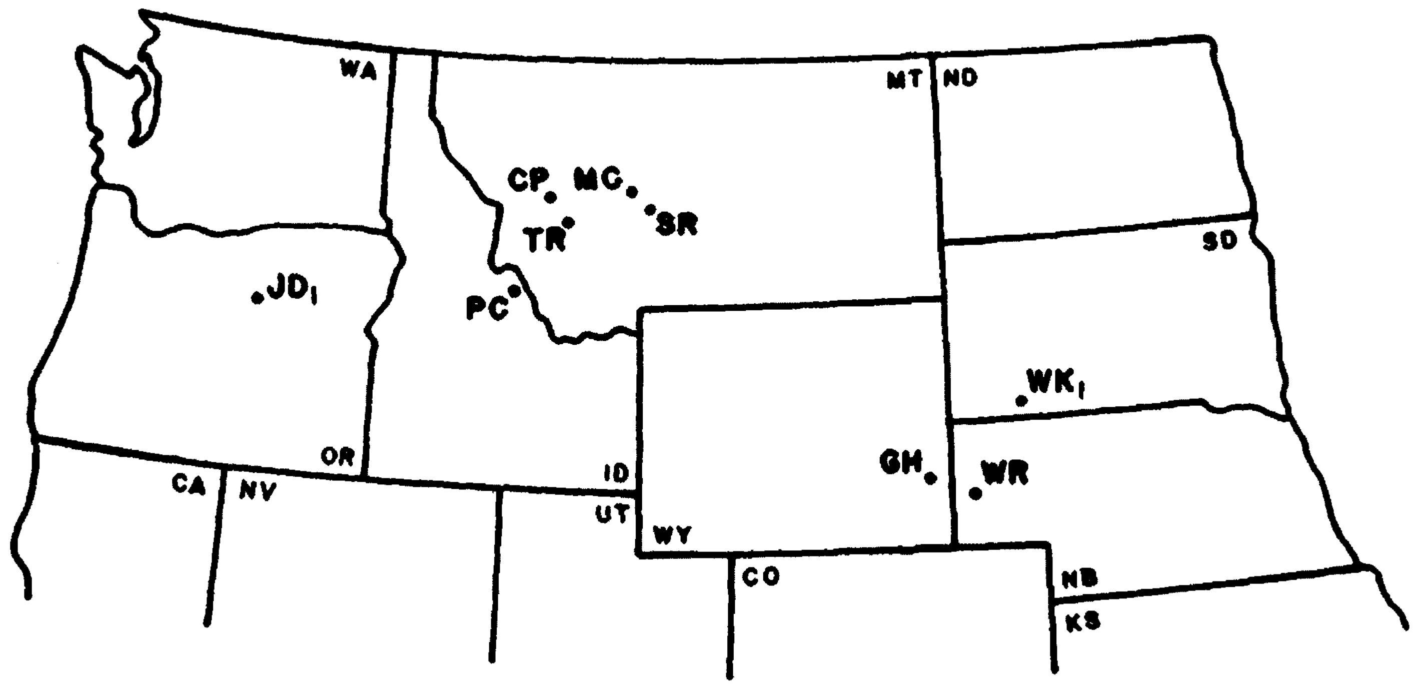

Figure 1. Location of Early Arikareean faunas used in this study. JD_1, John Day fauna (lower); PC, Peterson Creek Local fauna; CP, Cabbage Patch local faunas; TR, Tavenner Ranch local fauna; MC, Magpie Creek local fauna; SR, Smith River fauna; GH, Goshen Hole fauna; WR, Wildcat Ridge fauna; WK_1, Wounded Knee fauna (lower).

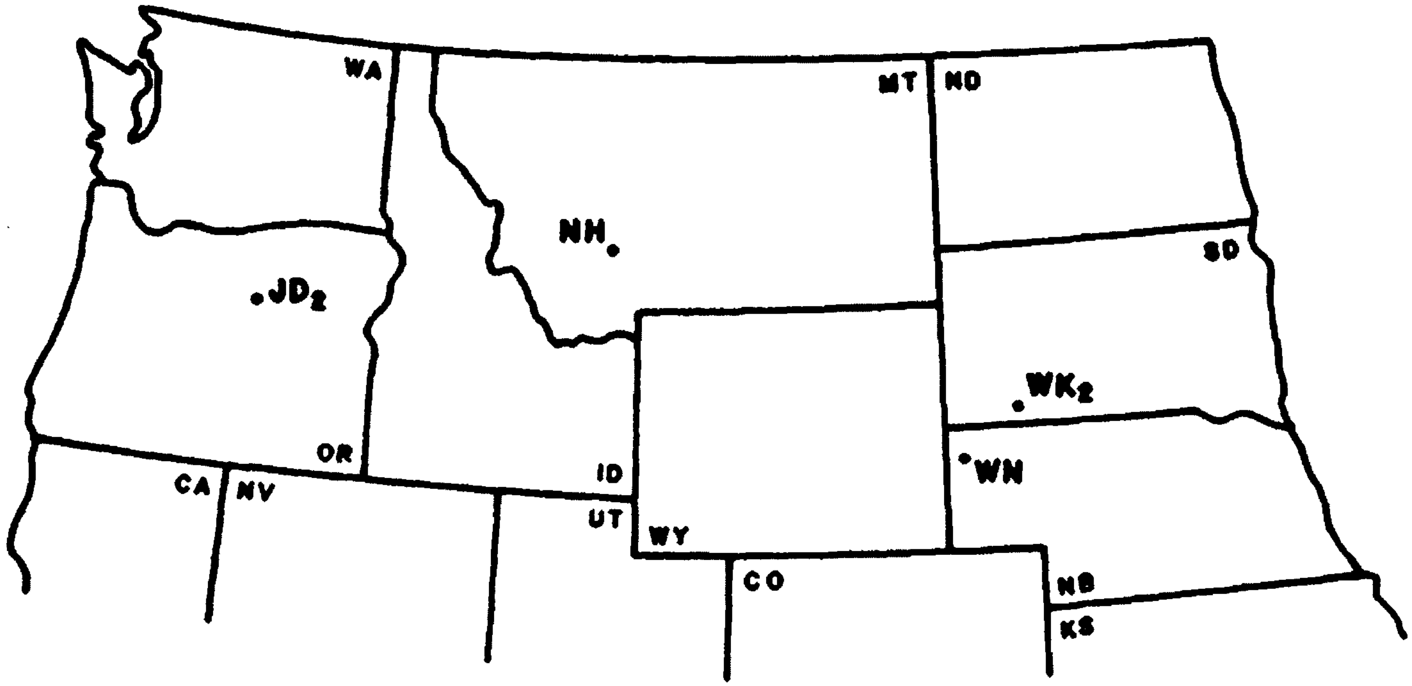

Figure 2. Location of Late Arikareean faunas used in this study. JD_2, John Day fauna (upper); NH, Negro Hollow local fauna; WN, western Nebraska composite fauna; WK_2, Wounded Knee fauna (upper).

Table 1. References used to compile faunal lists.

Fauna	Reference
EARLY ARIKAREEAN	
John Day fauna (lower)	Coombs (1978), Green (1956), Martin (1973), Merriam and Sinclair (1907), Rensberger (1971, 1973a, 1983), Rose and Rensberger (1983), Schultz and Falkenbach (1947, 1949, 1950, 1954, 1968), Striton and Rensberger (1964), Wahlert (1976), Woodburne (1969) Burke Memorial Washington State Museum (Seattle, WA), University of California Museum of Paleontology (Berkeley, CA)
Peterson Creek local fauna	Nichols (1976, 1979), Rensberger (1983)
Cabbage Patch local faunas	Rasmussen (1977)
Tavenner Ranch local fauna	Rasmussen (1977), Wood and Konizeski (1965)
Magpie Creek local fauna	Schultz and Falkenbach (1949, 1954, 1968), White (1954) University of Montana Museum of Paleontology (Missoula, MT)
Smith River fauna	Black (1961), Koerner (1939, 1940), Matthew (1909), Runkel (1986), Schultz and Falkenbach (1949, 1954, 1968), Scott (1893), Burke Memorial Washington State Museum (Seattle, WA), University of Montana Museum of Paleontology (Missoula, MT)
Goshen Hole fauna	Black (1961), Dawson (1958), Martin (1973), McKenna and Love (1972), Schlaikjer (1935), Schultz and Falkenbach (1954, 1968), Striton (1940)
Wildcat Ridge fauna	Martin (1973, 1974), McKenna and Love (1972), Schultz and Falkenbach (1949, 1954, 1968)

Fauna	Reference
EARLY ARIKAREEAN (CONT.)	
Wounded Knee fauna (lower)	Green (1977), Martin (1973), MacDonald (1963, 1970), MacDonald (1972), Rensberger (1973b, 1979, 1980), Rich and Rasmussen (1973)
LATE ARIKAREEAN	
John Day fauna (upper)	Fisher and Rensberger (1973), Green (1956), Orr and Orr (1981), Rensberger (1973a)
Negro Hollow local fauna	Lofgren (1985), Schultz and Falkenbach (1950, 1954) University of Montana Museum of Paleontology (Missoula, MT)
western Nebraska composite fauna	Coombs (1978), Frick (1937), Frick and Taylor (1971), Hunt (1981, 1985), Hutchison (1972), Matthew (1926), McGrew (1937, 1941), Patton and Taylor (1971), Riggs (1942), Schultz and Falkenbach (1940, 1941, 1947, 1949, 1950, 1954), Wood (1935, 1936), Woodburne and others (1974)
Wounded Knee fauna (upper)	Green (1977), Green and Martin (1976), MacDonald (1963, 1970), Rensberger (1973b), Schultz and Falkenbach (1940, 1947, 1950, 1954)

by subjecting the faunal similarity measurements to cluster analysis. I have followed the basic methodology of Flessa (1981) for this study.

Six similarity coefficients were used to measure faunal similarity (Fig. 3): Jaccard, First Kulczynski, Dice, Second Kulczynski, Simpson, and Simple Matching. The Jaccard and Simpson coefficients are the most widely used measures of bioassociational (faunal) similarity (Fallaw, 1979).

The Jaccard, First Kulczynski, and Dice coefficients were used because they emphasize differences between faunas (Cheetham and Hazel, 1969; Fallaw, 1979). The Second Kulczynski and Simpson coefficients were used because they emphasize similarities between faunas (Cheetham and Hazel, 1969). The Simple Matching coefficient was used because it emphasizes neither differences nor similarities between faunas (Cheetham and Hazel, 1969). Each similarity coefficient gives different results because each one emphasizes differently the variables used (i.e. N_1, N_2, C, A; see Fig. 3), and because each formula behaves mathematically different (Brown and Gibson, 1983). Thus, a variety of similarity coefficients were used to avoid biasing the results.

The Jaccard coefficient is a reliable indicator of faunal similarity if the sample sizes are approximately

Jaccard	$\frac{C}{N_1 + N_2 - C}$
First Kulczynski	$\frac{C}{N_1 + N_2 - 2C}$
Dice	$\frac{2C}{N_1 + N_2}$
Second Kulczynski	$\frac{C(N_1 + N_2)}{2(N_1N_2)}$
Simpson	$\frac{C}{N_1}$
Simple Matching	$\frac{C + A}{N_1 + N_2 - C + A}$

N_1=total number of taxa in smallest sample
N_2=total number of taxa in largest sample
C=taxa present in both samples
A=taxa absent in both samples

Figure 3. Similarity coefficients used in this study.

equal (Simpson, 1960). However, as N_2 (see Fig. 3) becomes larger relative to N_1, the faunal similarity measured cannot have a maximum value of 1.0 (or 100%), and will therefore be underestimated (Simpson, 1960). The First Kulczynski coefficient is slightly more reliable in this same situation, but has to be rescaled to a zero to one scale, since it can have a value of greater than one.

The Dice coefficient is more reliable than the Jaccard or First Kulczynski coefficients as N_2 becomes larger, since C is not in the denominator and is multiplied by two in the numerator (see Fig. 3). However, all of these similarity coefficients still emphasize differences.

The Simpson coefficient is a reliable indicator of faunal similarity for unequal sample sizes. The effect of unequal sample size is minimized by having only the smaller sample (N_1) in the denominator (see Fig. 3) (Simpson, 1960). However, I have observed that the Simpson coefficient will overestimate faunal similarity if the sample sizes become greatly unequal.

The Second Kulczynski coefficient minimizes the effect of unequal sample size by including both samples (N_1 and N_2) in the numerator and denominator.

The Simple Matching coefficient is unique from the other similarity coefficients discussed early in that mutual absences (A) are included in the formula (see Fig.

3). Here, the faunal similarity not only depends on the number of shared taxa, but also depends on the number of taxa absent in both samples.

Analyses were performed using the VAX8600 computer system at the University of Montana. The cluster analysis consisted of setting up data files in EMACS (an editor), which contained the faunal list data (see Appendix A). These data files were then analyzed in SPSS^x (a statistical software package; SPSS^x Inc., 1986). The data files were analyzed by the PROXIMITIES and CLUSTER procedures in SPSS^x (see Appendix A). The PROXIMITIES procedure calculates the similarity coefficient value and produces a similarity coefficient matrix. The CLUSTER procedure reads the similarity coefficient matrix produced by PROXIMITIES and creates a dendrogram (or tree diagram). The dendrogram shows "clusters" of faunas similar in content. These "clusters" will be used to define regions of similarity.

The PROXIMITIES procedure was not equipped to calculate the similarity coefficient values for the Simpson coefficient. Therefore, I calculated the Simpson coefficient values with a calculator and set up a separate data file to be analyzed by the CLUSTER procedure (see Appendix A).

Various kinds of clustering methods exist (Sneath and Sokal, 1973). I used the unweighted pair-group method using arithmetic averages (UPGMA) because it is the most common clustering method used and because Sokal and Rohlf (1962), Farris (1969), and Sneath and Sokal (1973) have shown that this clustering method produces the least distorted dendrogram.

All Early and Late Arikareean mammalian genera were subjected separately to this method of cluster analysis. In addition, Early Arikareean rodent and oreodont genera were analyzed separately and Late Arikareean perissodactyls and artiodactyls were analyzed separately, since their fossil record is exceptional. Also, the regions of similarity detected by the quantitative analysis of Early Arikareean mammalian genera will be analyzed separately.

One way to detect boundaries between faunal regions is to note any sharp changes in similarity values when one fauna is compared to the others (Flynn, 1986). Examples of sharp gradient changes were looked for in the various similarity matrices. I chose to look for sharp gradient changes in similarity values that compared the John Day fauna (JD_1) and the Wounded Knee fauna (WK_1) with the other faunas. This analysis was only done for Early Arikareean data, since Late Arikareean data are suspect. The end points of the northwest (i.e. the John Day fauna (JD_1) and the Wounded Knee fauna (WK_1)) were chosen as starting points because it is desirable to see sharp gradient changes across the whole area.

GEOLOGIC SETTING

Three distinct geographical and depositional regions existed in the northwest region of the United States during the Arikareean: the John Day region of Oregon; the Montana-Idaho intermontane basin region; and the northern Great Plains region of Wyoming, Nebraska, and South Dakota (Fig. 4 and 5).

The John Day region in the Arikareean consisted of two basins (western and eastern John Day basins), which were separated by the Blue Mountain High (Fig. 5) (Fisher and Rensberger, 1972). These basins were established earlier in the Tertiary (Nilsen and McKee, 1979).

The John Day Formation was deposited in these two basins. The John Day Formation is composed of mostly tan to green to red to gray, fine- to coarse-grained, massive, tuffaceous claystone, siltstone, and sandstone, and minor amounts of conglomerate (Fisher and Rensberger, 1972). A few air-fall tuff and welded tuff layers occur in places. The John Day Formation was deposited by fluvial and lacustrine processes, which reworked volcanic tephra that initially accumulated as a blanket on the surface

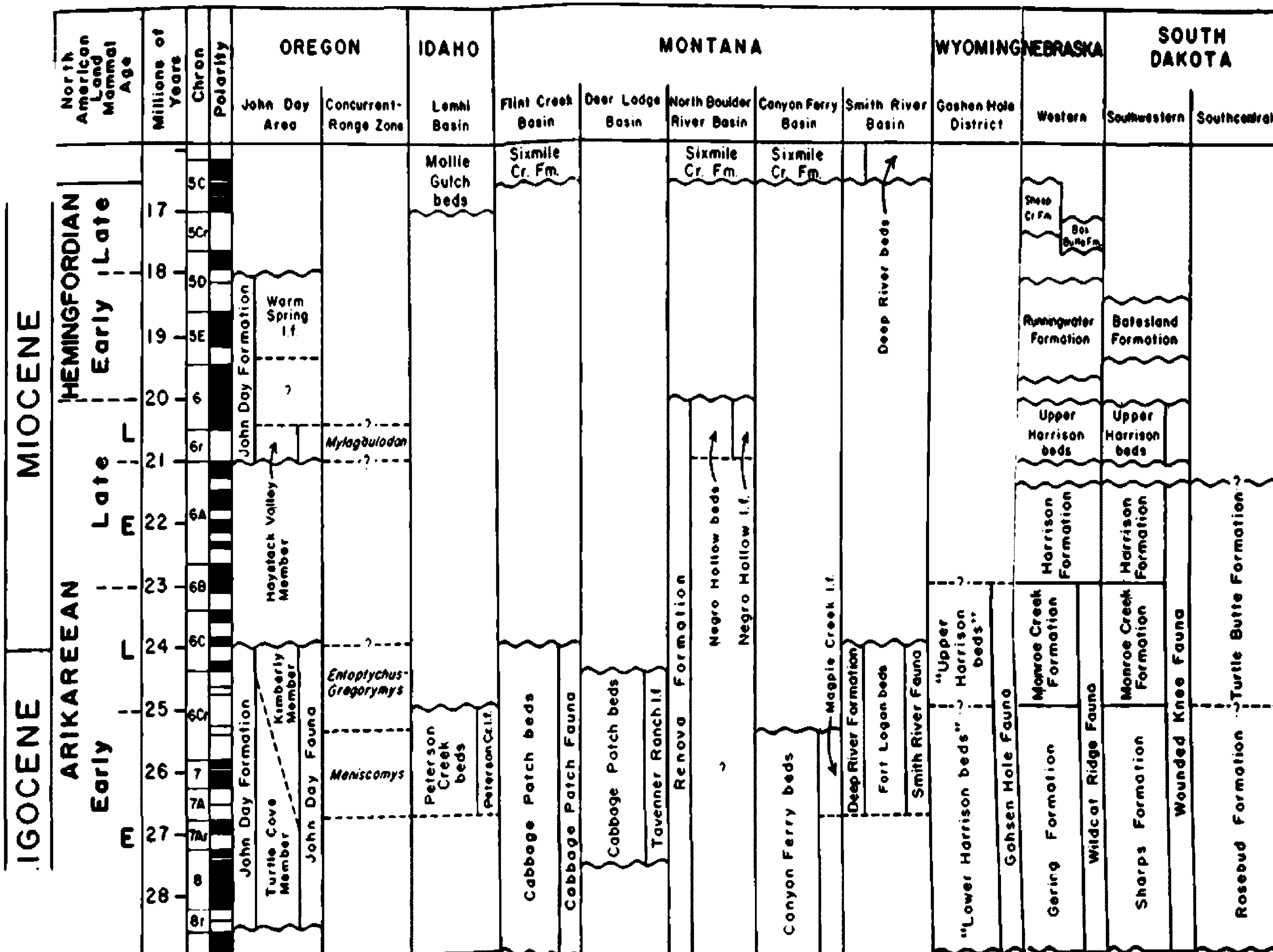

Figure 4. Correlation chart of Arikareean faunas. Based on data from: Fisher and Rensberger (1972), Prothero and Rensberger (1985) (Oregon); Nichols (1976, 1979) (Idaho); White (1954), Rasmussen (1977), Rensberger (1979, 1981), Fields and others (1985), Lofgren (1985), Runkel (Montana); Schlaikjer (1935), MacDonald (1970) (Wyoming); Hunt (1981), Tedford and others (in press) (Nebraska); and MacDonald (1963, 1970), Skinner and others (1968), Tedford and others (in press) (South Dakota).

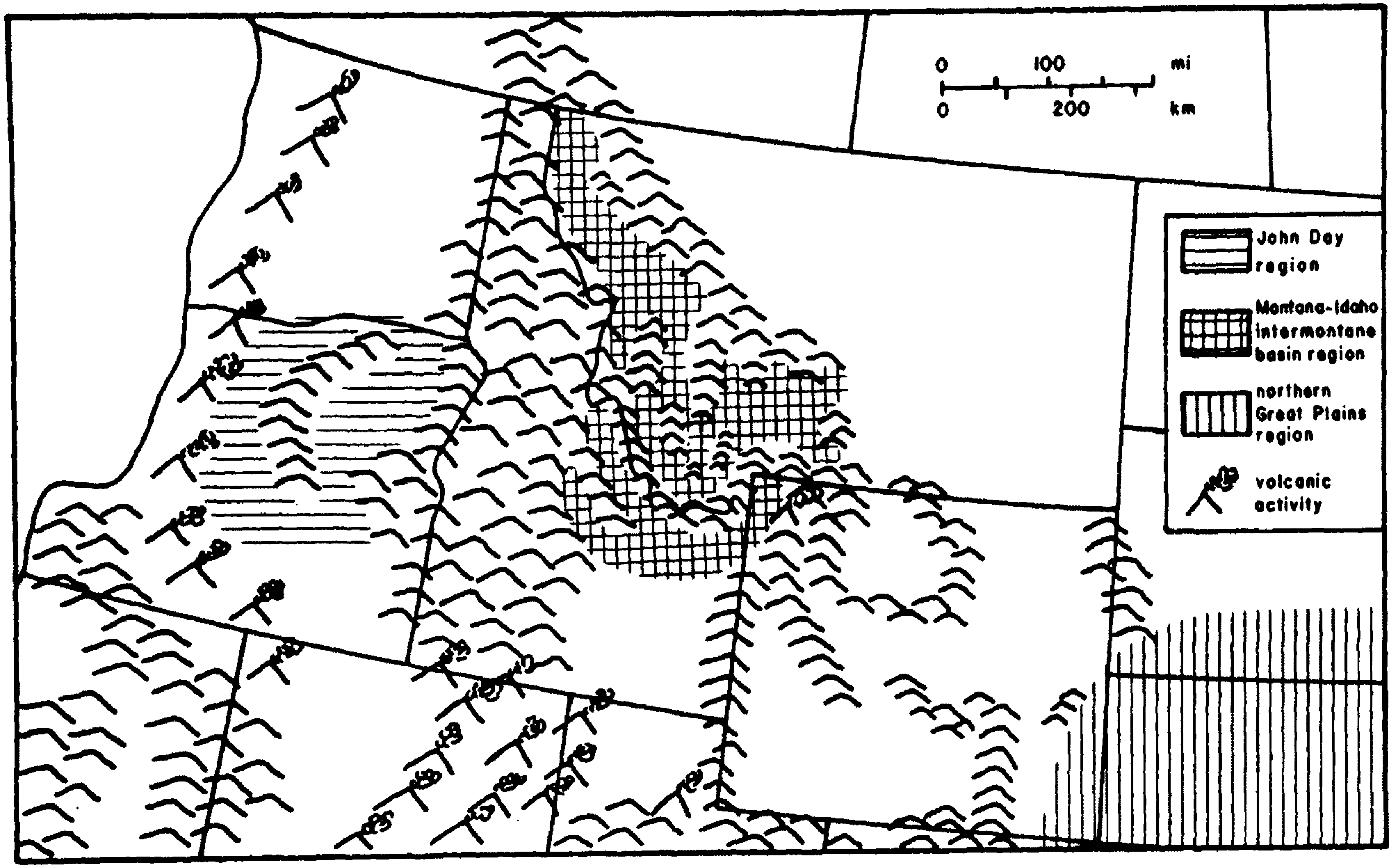

Figure 5. Arikareean Paleogeography of the northwest region of the United States. Compiled using data from Fisher and Rensberger (1972), Rasmussen (1977), Nilsen and McKee (1979), Seeland (1985), and Swinehart and others (1985).

(McKee, 1972).

The John Day Formation in the western John Day basin is thicker (approx. 4000') than it is in the eastern John Day basin (approx. 2500') (Fisher and Rensberger, 1972). According to Fisher and Rensberger (1972), this indicates a western source area for the volcanics. Indeed, subduction in this area of the west coast produced active subaerial volcanism in Oregon and Washington (Nilsen and McKee, 1979). This volcanism was probably one of the major sources for the huge quantities of volcanic tephra present in continental rocks of this age (Nilsen and McKee, 1979; Fields and others, 1985; Seeland, 1985).

Fisher and Rensberger (1972) have divided the John Day Formation into three members: Turtle Cove, Kimberly, and Haystack Valley members (Fig. 4). An unconformity exists between the Kimberly Member and the overlying Haystack Valley Member. Recently, a magnetostratigraphic study of the John Day Formation by Prothero and Rensberger (1985) has showed that most of the John Day Formation is Early Arikareean in age (Fig. 4). In this same study, the Haystack Valley Member showed no characteristic signature for accurate age placement on the magnetic time scale. Both Fisher and Rensberger (1972) and Prothero and Rensberger (1985) assigned the Haystack Valley Member to the Hemingfordian land-mammal age. However, based on fossil evidence, the Haystack Valley Member could be as old as Late Arikareean in age (personal observation). In this study, I have assigned the Haystack Valley Member to the Late Arikareean.

A basin and range province was present in western Montana and eastern Idaho during the Arikareean (Fig. 5) (Fields and others, 1985). These basins were broad, shallow, and surrounded by low relief mountains (Fields and others, 1985). The topographically high areas consisted of large Cretaceous batholiths and uplifted fault blocks of pre-Tertiary rock (Rasmussen, 1977).

Several different rock formations were deposited at this time in western Montana and eastern Idaho (Fields and others, 1985) (Fig. 4). These formations were deposited under basin-fill conditions, and are characterized by tan to gray, fine- to medium-grained, massive, tuffaceous claystone, mudstone, siltstone, and sandstone, with minor amounts of conglomerate, marl, and freshwater limestone. These volcanic ash rich sediments were deposited as a result of volcanic ash that initially accumulated on the surface of the terrain, and was subsequently reworked by fluvial and to a lesser extent lacustrine processes. The types of deposits included braided and meandering stream, debris flow, sheetflood, and ephemeral lake deposits.

A plains topography was present in the northern Great Plains region during the Arikareean (Fig. 5) (Hunt, 1981; Seeland, 1985; Swinehart and others, 1985). Deposition of the lower half of the Arikaree Group occurred on this plain at this time (Fig. 4). Arikaree Group rocks contain predominately tan to pinkish tan to grayish tan, very fine- to medium-grained, tuffaceous claystones, siltstones, and sandstones, with minor amounts of conglomerates and freshwater limestones (MacDonald, 1963, 1970; Skinner and others, 1968; Martin, 1973; Hunt, 1981). "Potato" and/or "pipy" calcareous concretions occur in places (MacDonald, 1963, 1970; Martin, 1973).

The Arikaree Group represents the accumulation of air-fall volcanic ash intermixed with locally derived epiclastic debris (Hunt, 1981). Arikaree Group sediments initially accumulated on the surface as a blanket of air-fall volcanic ash, that was subsequently reworked by fluvial and eolian processes (Hunt, 1981). The freshwater limestones were deposited by ephemeral lakes (Hunt, 1981).

The depositional and geographic history of the northern Great Plains presented here is based on the work of Hunt (1981), Seeland (1985), and Swinehart and others (1985). A plains topography existed in this region, which was being dissected by west-east trending streams coming from the Front Ranges of the ancestral Rocky Mountains.

Filling of these west-east trending streams started with the deposition of the Gering and Sharps formations, which consisted of alluvial deposits grading upward into eolian deposits. After the streams were filled in by the deposition of the Gering and Sharps formations, an aggrading plain existed while the Monroe Creek and Harrison formations were deposited. These two formations consisted of volcaniclastic eolian deposits with minor amounts of ephemeral stream and lake deposits. A minor erosional period occurred after the deposition of the Harrison Formation, forming valleys of low relief. These valleys were then subsequently filled up with volcaniclastic alluvial deposits grading upward into volcaniclastic eolian deposits and minor ephemeral stream and lake deposits of the Upper Harrison beds. When the upper part of the Upper Harrison beds were being deposited, an aggrading plain was present again.

Arikareean rocks in the northwest region of the United States contain mostly volcanic ash. Upon review of Arikareean stratigraphy and sedimentation, it can be said that most Arikareean sediments represent the initial accumulation of air-fall volcanic ash on the surface and their subsequent reworking by flooding events, which produced sheetflood, debris flow, and braided and meandering stream deposits, and later eolian and ephemeral stream and lake deposits. The source of the volcanic ash was probably the Cascades (McKee, 1973; Nilsen and McKee, 1979), the Jackson Hole area (Barnosky, 1984, 1986), and the Great Basin (Nilsen and McKee, 1979).

The climate over the northwest region of the United States during the Arikareean was probably semi-arid to arid (Thompson and others, 1982; Retallack, 1983; Loope, 1986). Keller (1965) and Barshad (1966) have shown that certain climates produce particular clay species. Dry climates produce smectite rich soil or sediment, and wet climates produce kaolinite rich soil or sediment. A study of clay composition in the Montana and Idaho Tertiary basin fill sediments by Thompson and others (1982) showed that the bulk of the Tertiary sediments have smectite as the clay species. Only two weathered horizons, which mark two major unconformities in the Tertiary of Montana and Idaho, have kaolinite as the clay species. Thompson and others (1982) suggest that this indicates most of the Montana and Idaho Tertiary basin fill sediments were deposited under arid conditions.

Loope (1986) has suggested that diagenetic features in the Gering Formation indicate deposition occurred in an arid environment. Loope finds rosettes of calcite-cemented sand within the Gering Formation, which may represent pseudomorphs after gypsum.

Retallack (1983) has suggested that the presence of tuffaceous siltstones of the Sharps Formation indicate an arid climate because the ash has not been weathered to clay, as in the Lower Brule Formation claystones (Middle Oligocene.

Thompson and others (1982) also note that basin fill deposition usually occurs in arid to semi-arid environments, since there is more sediment production than erosion (i.e. net deposition). This is due to lack of vegetation, low rainfall, and internal drainage systems.

RESULTS AND DISCUSSION

Observational Analysis

Three distinct geographical and depositional regions existed in the northwest region of the United States during the Arikareean. These are based on depositional environments and geography (Fig. 4 and 5) (see geologic setting section). These were the John Day region, the Montana-Idaho intermontane basin region, and the northern Great Plains region. To make the observational analysis simpler, I will recognize these regions rather than the individual faunas themselves, since each region was probably characterized by its own ecological and environmental conditions.

Early Arikareean— In the Early Arikareean, each region contained the following number of genera (Fig. 6):

1) the John Day region had 58 genera.

2) the Montana-Idaho intermontane basin region had 58 genera.

3) the northern Great Plains region had 104 genera.

The three regions were also compared to each other and the following results were obtained (Fig. 6):

1) the John Day region and The Montana-Idaho intermontane region had 19 genera in common.

2) the Montana-Idaho intermontane basin region and northern Great Plains region had 46 genera in common.

3) the John Day region and the northern Great Plains region had 32 genera in common.

These results indicate that the John Day region is somewhat isolated from the other regions, since it has the least number of genera in common with the other regions. Also, the Montana-Idaho intermontane basin region and the northern Great Plains region share the greatest similarity, since these two regions have the most genera in common.

Examination of endemic genera to each region yield the following results (Fig. 7 and Table 2):

1) the John Day region had 22 endemic genera.

2) the Montana-Idaho intermontane basin region had eight endemic genera.

3) the northern Great Plains region had 40 endemic genera.

These results indicate that the John Day and northern Great Plains regions formed two isolated regions, because they contain the most endemic genera. The Montana-Idaho intermontane basin region contained the least endemic genera, which suggests mixing of genera from the other regions.

The following results were obtained when comparing endemic genera between regions (Fig. 7 and Table 3 and 4):

1) three genera are endemic to the John Day and Montana-Idaho intermontane basin regions.

2) 33 genera are endemic to the Montana-Idaho intermontane and northern Great Plains regions.

3) 16 genera are endemic (disjunct) to the John Day and northern Great Plains regions.

4) 17 genera are "cosmopolitan" (occur in all the areas).

These results indicate that the John Day region had the least in common with the other regions (i.e. is the most isolated area) and the Montana-Idaho intermontane basin region and the northern Great Plains region share the most

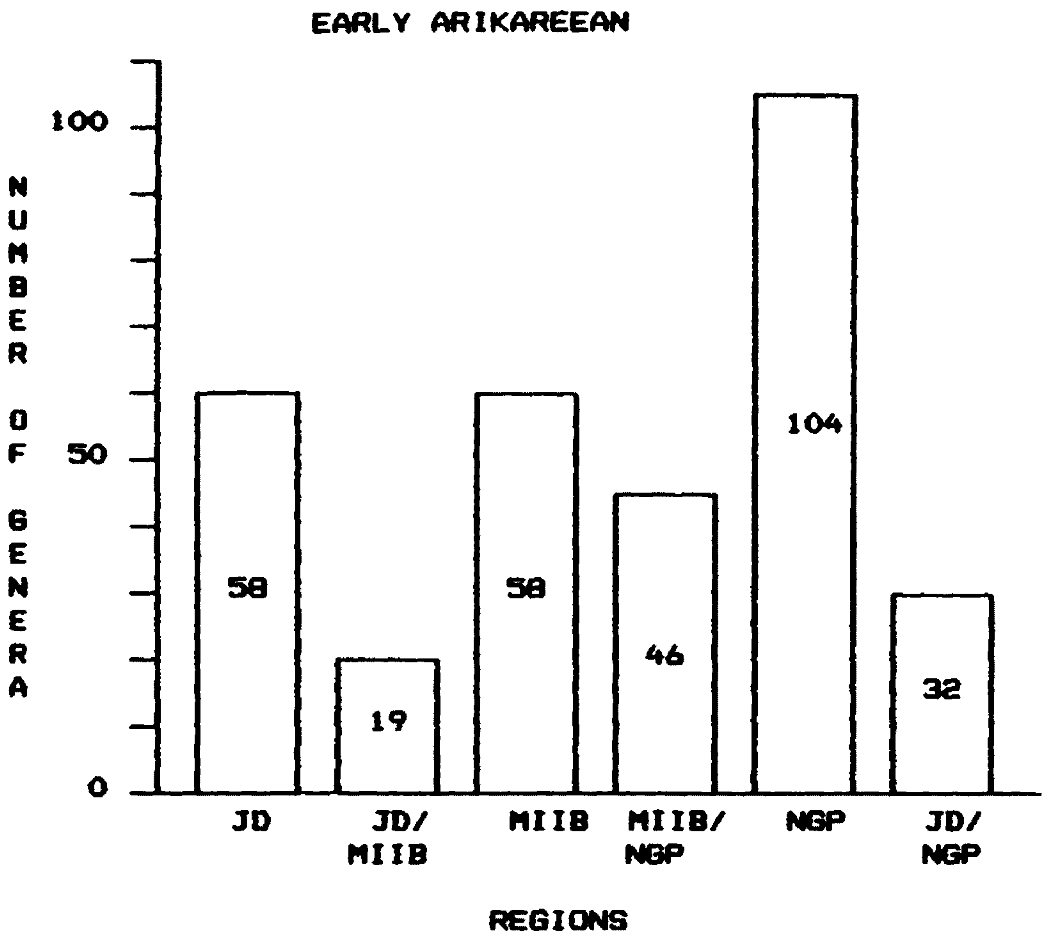

Figure 6. Bar chart of the number of Early Arikareean genera in and between regions. JD, John Day region; MIIB, Montana-Idaho intermontane basin region; NGP, northern Great Plains region.

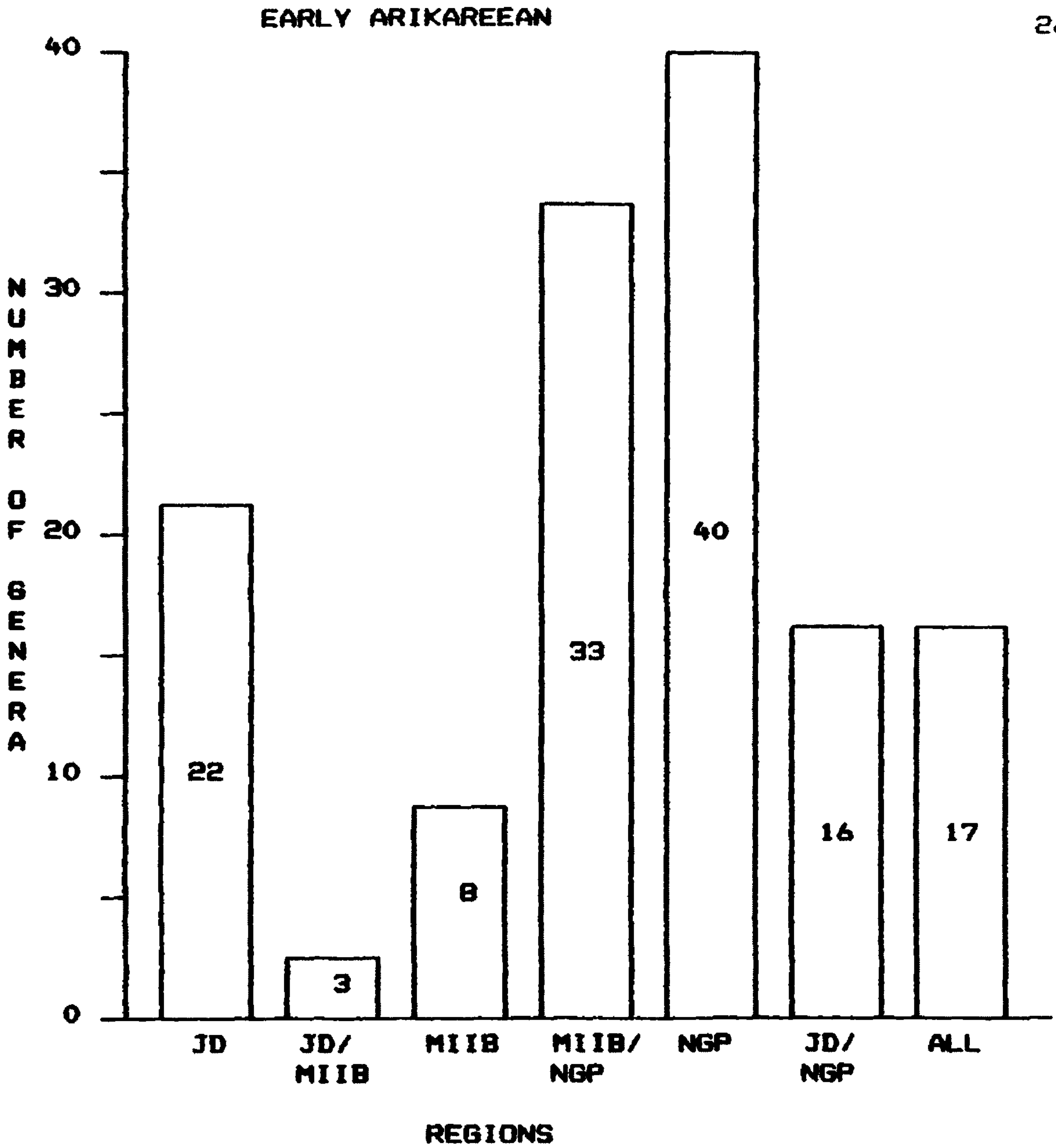

Figure 7. Bar chart of the number of Early Arikareean mammalian genera endemic to and between regions. JD, John Day region; MIIB, Montana-Idaho intermontane basin region; NGP, northern Great Plains region; All, cosmopolitan.

TABLE 2. Endemic mammalian genera in each region during the Early Arikareean.

John Day region	Montana-Idaho intermontane basin region	Northern Great Plains region
Micropternodus	Stenoechinus	Proterix
Rudiomys	Mystipterus	Metechinus
Swelleladon	Oreolagus	Geolabis
Alwoodia	Fossodontia	Nebraskerix
Miosciurus	?Euphaopsis	Plesiosorex
Jimomys	Agnotocastor	Scalopoides
Parictis	Kukusepasutanka	Pseudotheriomys
Allocyon	Pronodens	Prosciurus
Paradaphaenus		Crucimys
Dinaelurus		Tamias
Protapirus		Protomiospermophilus
Moropus		Miospermophilus
Cynorca		Sanctimus
Perchoerus		Heliscomys
Elotherium		Hitonkala
Hypsiops		Scottimus
Superdesmatochoerus		Geringia
Pseudogenetochoerus		Zetamys
Epigenetochoerus		Hyaenodon
Eporeodon		Hesperocyon
Dayohyus		Neocynodesmus
Gentilicamelus		Sunkahetanka
		Brachyrhynchocyon
		Plesictis
		Mammacyon
		Promartes
		Aleurocyon
		Parahippus
		Miotapirus
		Hyracodon
		Menoceras
		Leptochoerus
		Dinohyus
		Elomeryx
		Megasespia
		Leptauchenia
		Miotylopus
		Nanotragulus
		Leptomeryx
		Hypisodus
22 genera	8 genera	40 genera

TABLE 3. Distribution of Early Arikareean mammalian genera between regions.

Genera	John Day region	Montana-Idaho inter. basin region	Northern Great Plains region
Protospermophilus	<--------	-------->	
Promerycochoerus	<--------	-------->	
Hypertragulus	<--------	-------->	
Nanodelphys		<--------	-------->
Ocajila		<--------	-------->
Amphechinus		<--------	-------->
Parvericus		<--------	-------->
Domnina		<--------	-------->
Trimylus		<--------	-------->
Proscalops		<--------	-------->
Desmatolagus		<--------	-------->
Palaeolagus		<--------	-------->
Megalagus		<--------	-------->
Downsimus		<--------	-------->
Niglarodon		<--------	-------->
Promylagaulus		<--------	-------->
Penepalaeocastor		<--------	-------->
Capatanka		<--------	-------->
Patecastor		<--------	-------->
Eutypomys		<--------	-------->
Gregorymys		<--------	-------->
Tenudomys		<--------	-------->
Florentiamys		<--------	-------->
Eumys		<--------	-------->
Plesiosminthus		<--------	-------->
Cynodesmus		<--------	-------->
Arretotherium		<--------	-------->
Mesoreodon		<--------	-------->
Megoreodon		<--------	-------->
Paramerycoidodon		<--------	-------->
Sespia		<--------	-------->
Pithecistes		<--------	-------->
Cyclopidius		<--------	-------->
Hadroleptauchenia		<--------	-------->
Pseudocyclopidius		<--------	-------->
Ekgmowechashala	<--------		-------->
Protosciurus	<--------		-------->
Proheteromys	<--------		-------->
Philotrox	<--------		-------->
Enhydrocyon	<--------		-------->
Temnocyon	<--------		-------->
Paleogale	<--------		-------->
Oligobunis	<--------		-------->
Nimravus	<--------		-------->
Pogonodon	<--------		-------->
Ekgmoitepecela	<--------		-------->
Anchitherium	<--------		-------->
Chaenohyus	<--------		-------->
Agriochoerus	<--------		-------->
Oreodontoides	<--------		-------->
Oxydactylus	<--------		-------->

TABLE 4. Cosmopolitan genera in the northwest region of the United States during the Early Arikareean.

<table>
<tr><th>Genera</th><th>John Day region</th><th>Montana-Idaho inter. basin region</th><th>Northern Great Plains region</th></tr>
<tr><td>Peratherium</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Archaeolagus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Allomys</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Meniscomys</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Palaeocastor</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Capacikala</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Pleurolicus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Entoptychus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Leidymys</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Paciculus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Mesocyon</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Nothocyon</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Miohippus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Diceratherium</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Merycoides</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Desmatochoerus</td><td colspan="3"><---------------------------></td></tr>
<tr><td>Pseudodesmatochoerus</td><td colspan="3"><---------------------------></td></tr>
</table>

similarity. Most of the dispersal was from east to west and a barrier may have existed between the John Day and Montana-Idaho intermontane regions. The presence of "cosmopolitan" genera indicated that the regions were not completely separated and that some dispersal occurred between the regions. The disjunct genera (genera in common between the John Day and northern Great Plains regions) can be explained in two ways:

1) some or all of these genera are not present in the Montana-Idaho intermontane basin region because their dispersal route was to the south.
2) some or all of these genera have not yet been found in the Montana-Idaho intermontane basin region because this region has not been as extensively collected as the other two regions.

Late Arikareean—In the Late Arikareean, each region contained the following number of genera (Fig. 8):

1) the John Day region had 36 genera.
2) the Montana-Idaho intermontane basin region had 12 genera.
3) the northern Great Plains region had 67 genera.

The three regions were also compared to each other and the following results were obtained (Fig. 8):

1) the John Day and Montana-Idaho intermontane basin

region had four genera in common.

2) the Montana-Idaho intermontane basin and northern Great Plains regions had eight genera in common.

3) the John Day and northern Great Plains regions had 17 genera in common.

Caution must be taken when considering the Late Arikareean results, due to the nature of the data (as discussed in the Methods section). What can be said is that three faunal regions defined above in the observational analysis of Early Arikareean mammalian genera still existed in the Late Arikareean. More sampling in Montana would be needed to determine if the Montana-Idaho intermontane basin and northern Great Plains regions still shared the greatest similarity.

The number of endemic genera in each region is as follows (Fig. 9 and Table 5):

1) the John Day region had 17 endemic genera.

2) the Montana-Idaho intermontane basin region had two endemic genera.

3) the northern Great Plains region had 45 endemic genera.

As in the case for the Early Arikareean, the John Day and northern Great Plains regions contained the most endemic genera in the Late Arikareean. A larger sample from Montana would be needed to confirm this interpretation.

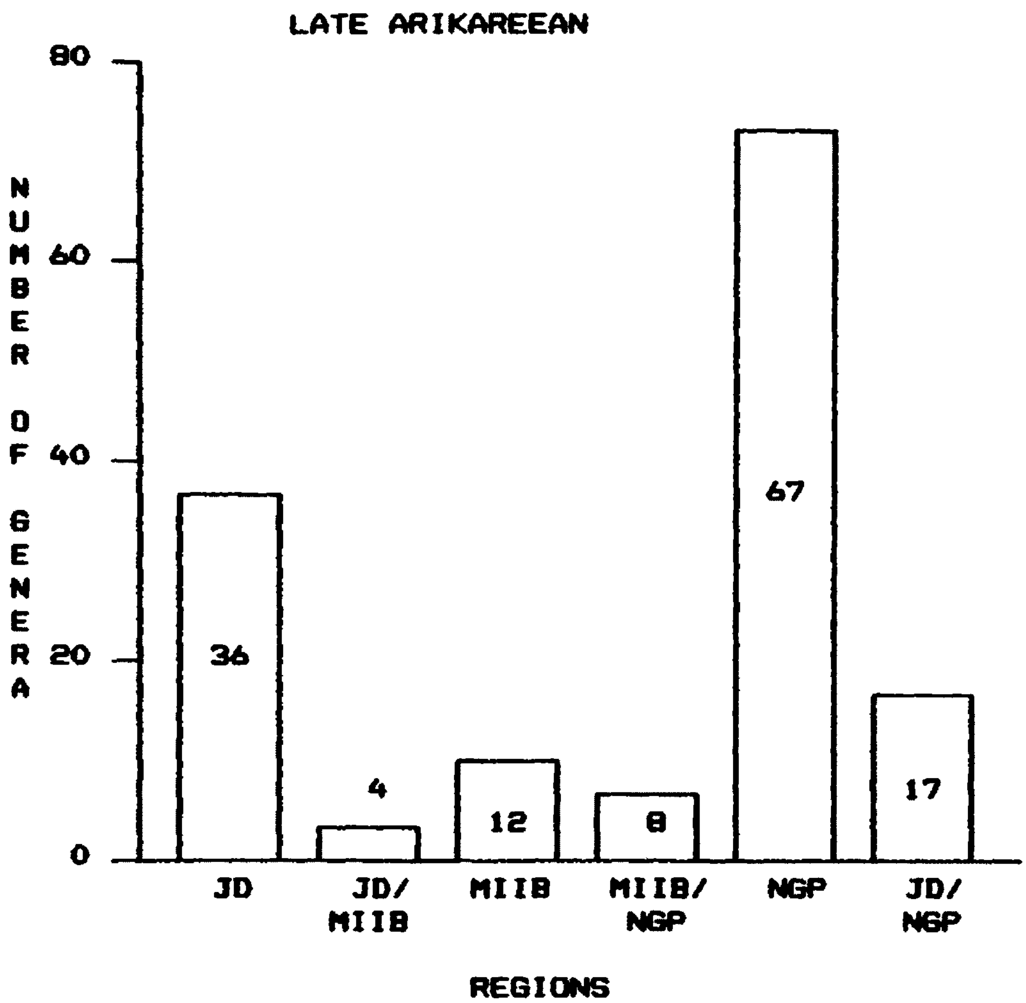

Figure 8. Bar chart of the number of Late Arikareean mammalian genera in and between regions. JD, John Day region; MIIB, Montana-Idaho intermontane basin region; NGP, northern Great Plains region.

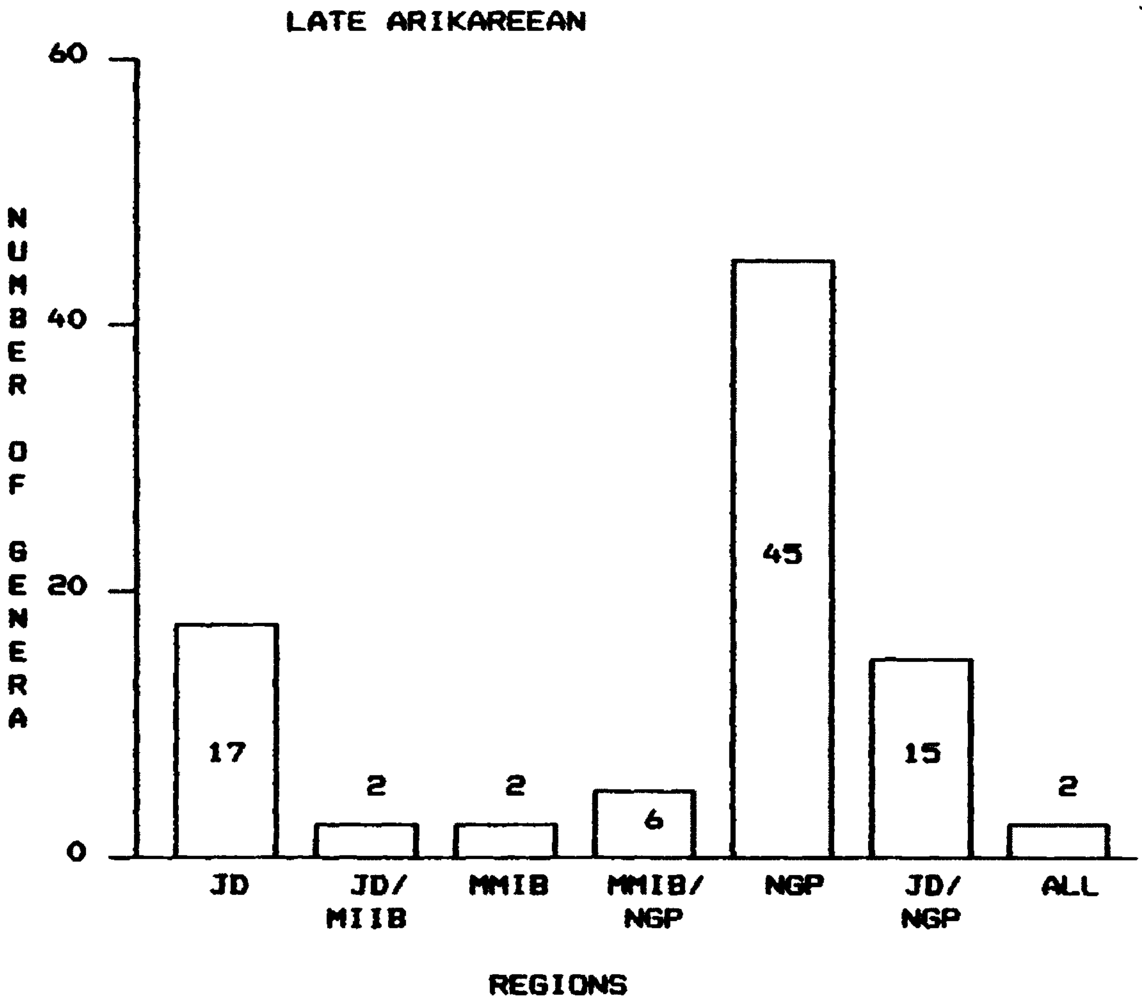

Figure 9. Bar chart of the number of Late Arikareean mammalian genera endemic in and between regions. JD, John Day region; MIIB, Montana-Idaho intermontane basin region; NGP, northern Great Plains region; All, cosmopolitan.

TABLE 5. Endemic mammalian genera in each region during the Late Arikareean.

John Day region	Montana-Idaho intermontane basin region	Northern Great Plains region
Protospermophilus	Pseudomesoreodon	Amphechinus
Paleocastor	Pseudodesmatochoerus	Heterosorex
Entoptychus		Proscalops
Paciculus		Mesoscalops
Parictis		Scalopoides
Paradaphaenus		Oreolagus
Nimravus		Gripholagus
Pogonodon		Archaeolagus
Thinohyus		Promylagaulus
Elotherium		Capatanka
Agriochoerus		Gregorymys
Oreodontoides		Dikkomys
Superdesmatochoerus		Heliscomys
Pseudogenetochoerus		Proheteromys
Eporeodon		Mookomys
Gentilicamelus		Plesiosminthus
Hypertragulus		Hesperocyon
		Cynodesmus
		Neocynodesmus
		Tomarctus
		Cynarctoides
		Phlaocyon
		Leptocyon
		Cephalogale
		Bassariscus
		Zodiolestes
		Mammacyon
		Cynelos
		Ysengrinia
		Daphoenodon
		Promartes
		Megalictis
		Parahippus
		Menoceras
		Cynorca
		Arretotherium
		Mediochoerus
		Merychyus
		Paramerychyus
		Phenacocoelus
		Megoreodon
		Michenia
		Protoceras
		Syndyoceras
		Machaeromeryx
17 genera	2 genera	45 genera

Table 6. Distribution of Late Arikareean mammalian genera between regions.

	John Day region	Montana-Idaho inter. basin region	Northern Great Plains region
Allomys	<--------	-------->	
Anchitherium	<--------	-------->	
Peratherium		<--------	-------->
Dinohyus		<--------	-------->
Hypsiops		<--------	-------->
Oxydactylus		<--------	-------->
Stenomylus		<--------	-------->
Nanotragulus		<--------	-------->
Mylagaulodon	<--------		-------->
Pleurolicus	<--------		-------->
Schizodontomys	<--------		-------->
Proheteromys	<--------		-------->
Mesocyon	<--------		-------->
Enhydrocyon	<--------		-------->
Temnocyon	<--------		-------->
Oligobunis	<--------		-------->
Miohippus	<--------		-------->
Moropus	<--------		-------->
Desmathyus	<--------		-------->
Merycochoerus	<--------		-------->
Promerycochoerus	<--------		-------->
Desmatochoerus	<--------		-------->
Blastomeryx	<--------		-------->
Nothocyon	<--------	--------	-------->
Diceratherium	<--------	--------	-------->

The number of genera endemic between regions is as follows (Fig. 9 and Table 6):

1) the John Day and Montana-Idaho intermontane basin regions had two endemic genera.
2) the Montana-Idaho intermontane basin and northern Great Plains regions had six endemic genera.
3) the John Day and northern Great Plains regions had 15 endemic genera.
4) there were two cosmopolitan genera present.

Again, the same general pattern is present here, as for the Early Arikareean.

It is apparent that the basic patterns present in Early Arikareean observational data are also present in Late Arikareean observational data. The results of the observational analysis suggest that three faunal regions existed during the Arikareean: the John Day region, the Montana-Idaho intermontane basin region, and the northern Great Plains region.

The John Day region is the most isolated region and is characterized by several endemic genera (Table 2 and 5). The most predominant endemic genera in this region are aplodontid rodents, ursid, amphicyonid and felid carnivores, tapirid and chalicotherid perissodactyls, tayassuids, and phenacocoeline, desmatochoerine, merycoidodontine, eporeodontine oreodonts.

The Montana-Idaho intermontane basin region is characterized by just a few endemic genera (Table 2 and 5). Only a few particular insectivores and rodents, a lagomorph, an anthracotherid, a leptomerycid, and two oreodont genera are endemic to this region.

The northern Great Plains region is characterized by several endemic genera (Table 2 and 5). The most predominant endemic genera were erinaceid, geolabidid, plesiosoricid, proscalopid insectivores, sciurid and cricetid rodents, hyaenodontid, canid, ursid, amphicyonid, procyonid, and mustelid carnivores, perissodactyls, artiodactyls, and leptauchenine oreodonts.

The Montana-Idaho intermontane basin region and the Northern Great Plains region share the greatest similarity (Table 3 and 6). A marsupial, several erinaceid, soricid, proscalopid insectivores, lagomorphs, aplodontid, mylagaulid, castorid, eutypomyid, geomyid, cricetid, zapodid rodents, a canid, an anthracotherid, and promerycochoerine, desmatochoerine, merycoidodontine, leptauchenine oreodonts are restricted to these two regions.

Cluster Analysis

The cluster analysis was conducted to see if the results obtained from the observational analysis agree with results obtained objectively. The location of the faunas are present in Figures 1 and 2.

Cluster analysis of all Early Arikareean mammalian genera- The dendrograms generated in the cluster analysis of all Early Arikareean mammalian genera show similar patterns (Fig. 10). The John Day fauna (JD_1) usually branches off low in the dendrogram, indicating that it has the least similarity with the other faunas. The remaining faunas (all of the Montana, Idaho, Wyoming, Nebraska, and South Dakota faunas) form one large group. However, this is where the similarity ends. Some differences are seen between the dendrograms based on similarity coefficients that emphasize differences between faunas (i.e. Jaccard, First Kulczynski, and Dice) and those dendrograms based on similarity coefficients that emphasize similarities between faunas (i.e. Second Kulczynski and Simpson). The dendrogram based on Simple Matching coefficient values shows an unusual pattern.

The dendrograms based on Jaccard, First Kulczynski, and Dice coefficient values all show the same pattern (Fig. 10). The Peterson Creek local fauna (PC) and the Magpie Creek local fauna (MC) both branch off before the John Day fauna (JD_1) in these dendrograms, suggesting that these two local faunas are more dissimilar to the other faunas than

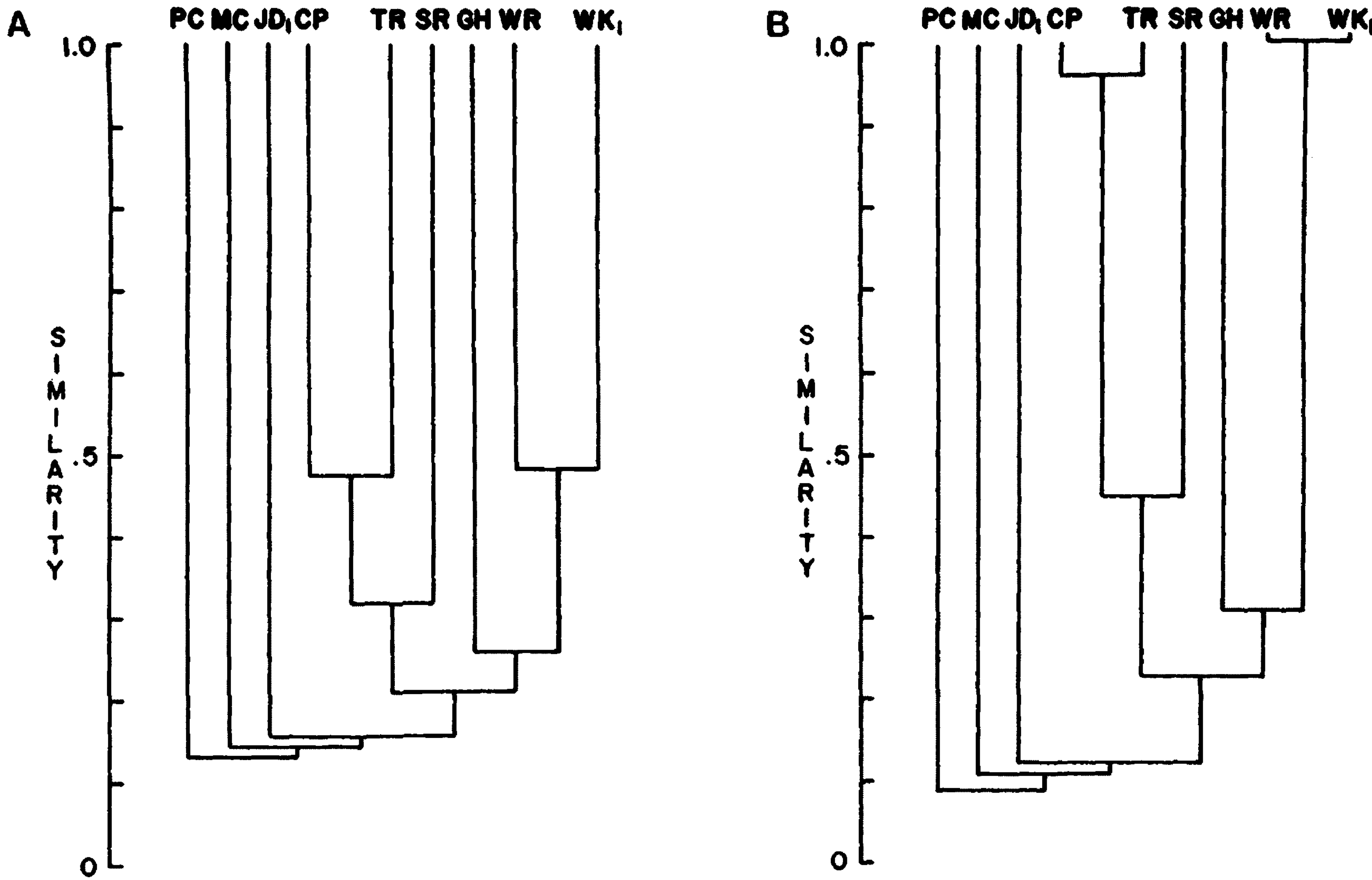

Figure 10. Dendrograms constructed in the cluster analysis of all Early Arikareean mammalian genera. A, dendrogram based on Jaccard coefficient values, r_{mc} (cophenetic correlation coefficient)=0.86; B, dendrogram based on First Kulczynski coefficient values, r_{mc}=0.92.

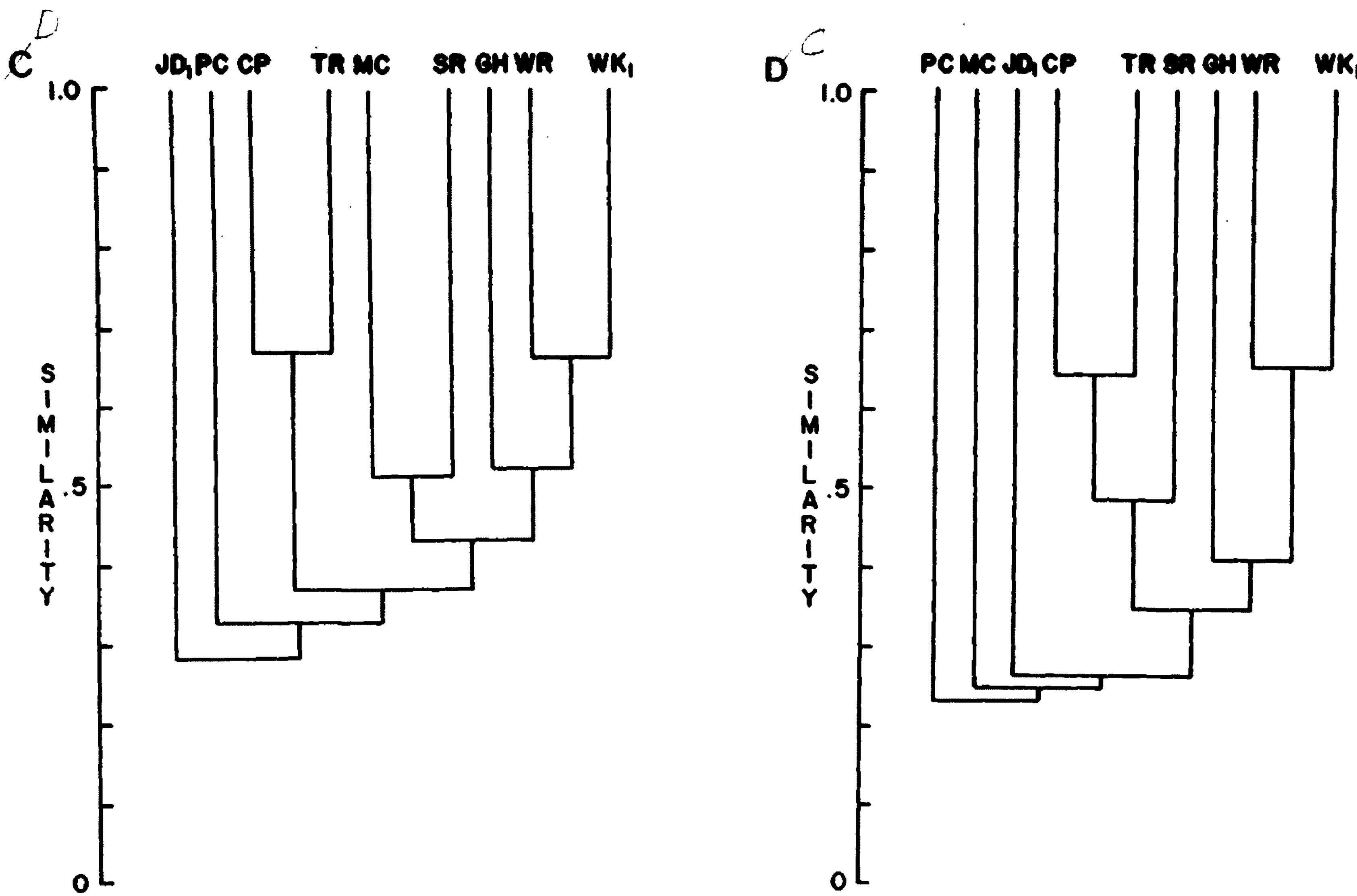

Figure 10. Continued. C, dendrogram based on Dice coefficient values, r_{sc}=0.82; D, dendrogram based on Second Kulczynski coefficient values, r_{sc}=0.72.

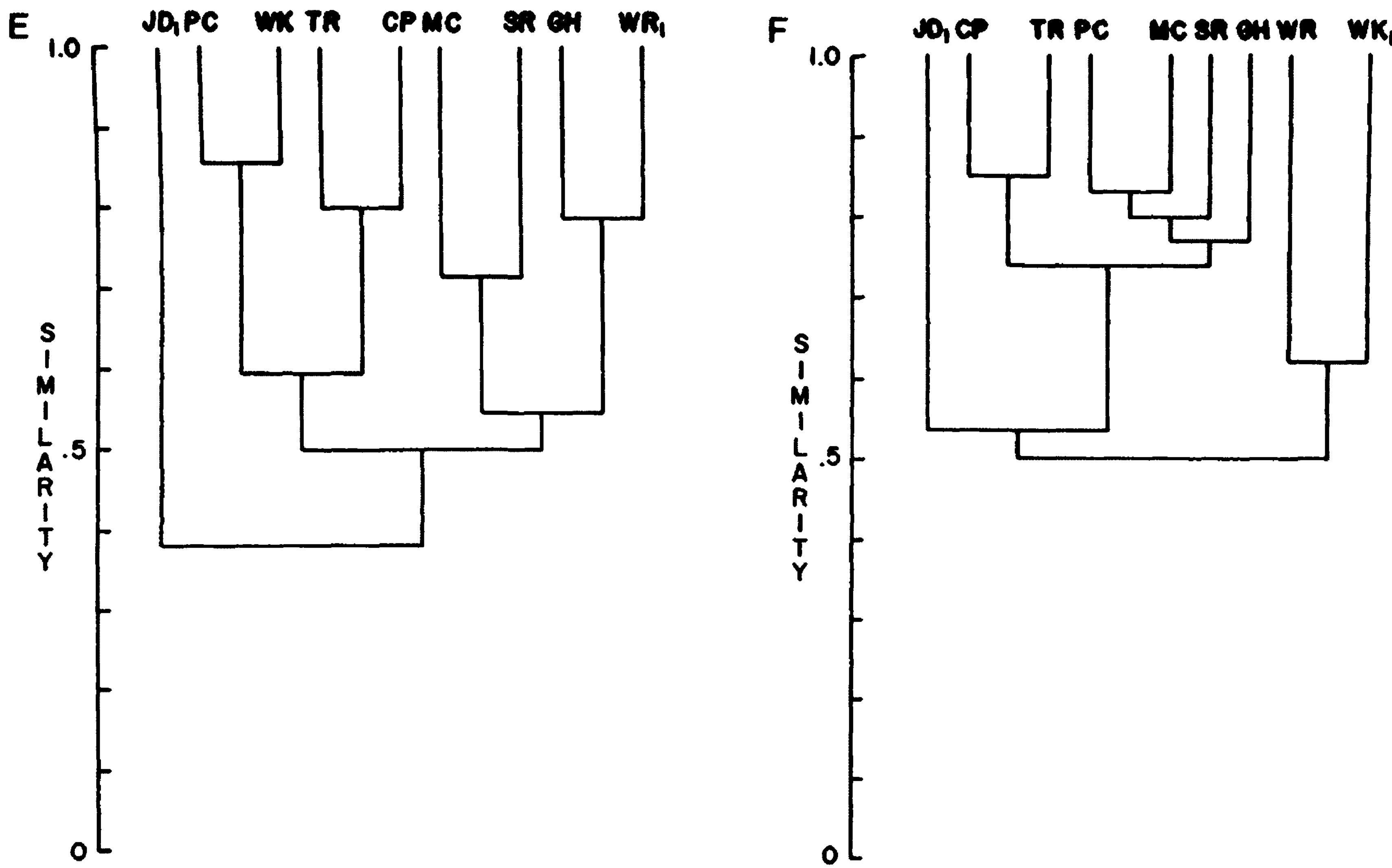

Figure 10. Continued. E, dendrogram based on Simpson coefficient values, r_{sc}=0.60; and F, dendrogram based on Simple Matching coefficient values, r_{sc}=0.92.

the John Day fauna (JD_1) and are more similar to the John Day fauna (JD_1) than any of the other faunas. Although this situation is plausible, I think that this pattern can be explained as an artifact of unequal sample size. The similarity values obtained using the Jaccard, First Kulczynski, and Dice coefficients between these two local faunas and the other faunas is grossly underestimated, because of the nature of these similarity coefficients (see discussion of similarity coefficients in the Methods section).

The John Day fauna (JD_1) branches off low in these dendrograms, indicating that this fauna forms a separate group. The remaining faunas form one large group. This large group is divided into two subgroups:

1) the first subgroup contains the Cabbage Patch local faunas (CP), the Tavenner Ranch local fauna (TR), and the Smith River fauna (SR).
2) the second subgroup contains the Goshen Hole fauna (GH), the Wildcat Ridge fauna (WR), and the Wounded Knee fauna (WK_1).

The dendrograms based on Second Kulczynski and Simpson coefficient values are somewhat different (Fig. 10). The dendrogram based on Second Kulczynski coefficient values shows the John Day fauna (JD_1) branching off first, indicating a separate group. The Peterson Creek local fauna (PC) branches off next, indicating more similarity to other faunas. In this case, the Peterson Creek local fauna (PC) can be associated either with the John Day fauna (JD_1) or the other faunas. A large group is present that consists of the remaining faunas. Two subgroups are within the larger group:

1) the first subgroup contains the Cabbage Patch local faunas (CP) and the Tavenner Ranch local fauna (TR).
2) the second subgroup is further subdivided into two groups; one contains the Magpie Creek local fauna (MC) and the Smith River fauna (SR), and the other contains the Goshen Hole fauna (GH), Wildcat Ridge fauna (WR), and the Wounded Knee fauna (WK_1).

The dendrogram based on Simpson coefficient values (Fig. 10) also shows the John Day fauna (JD_1) branching off first and the other faunas forming one large group. This large group is divided into two subgroups. The first subgroup contains two subdivisions:

1) the Peterson Creek local fauna (PC) and the Wounded Knee fauna (WK_1).
2) the Tavenner Ranch local fauna (TR) and the Cabbage Patch local faunas (CP).

The second subgroup also contains two subdivisions:

1) the Magpie Creek local fauna (MC) and the Smith

River fauna (SR)

2) the Goshen Hole fauna (GH) and the Wildcat Ridge fauna (WR).

The similarity between the Peterson Creek local fauna (PC) and the Wounded Knee fauna (WK_1) appears to have been overestimated, due to the nature of the Simpson coefficient (see discussion of similarity coefficients in the Methods section).

The dendrogram based on Simple Matching coefficient values shows an unusual pattern (Fig. 10). Here, the Wildcat Ridge fauna (WR) and the Wounded Knee fauna (WK_1) branch off first and form a separate group. The remaining cluster diagram consists of two groups. The first group contains only the John Day fauna (JD_1). The other group contains two subdivisions:

1) the Cabbage Patch local faunas (CP) and the Tavenner Ranch local fauna (TR).

2) the Peterson Creek local fauna (PC), the Magpie Creek local fauna (MC), the Smith River fauna (SR), and the Goshen Hole fauna (GH).

Cluster analysis of Early Arikareean rodent and oreodont genera– The dendrograms generated in cluster analysis of Early Arikareean rodent and oreodont genera are shown in Figure 11. Most of the dendrograms contain two groups. One group contains the John Day fauna (JD_1) and

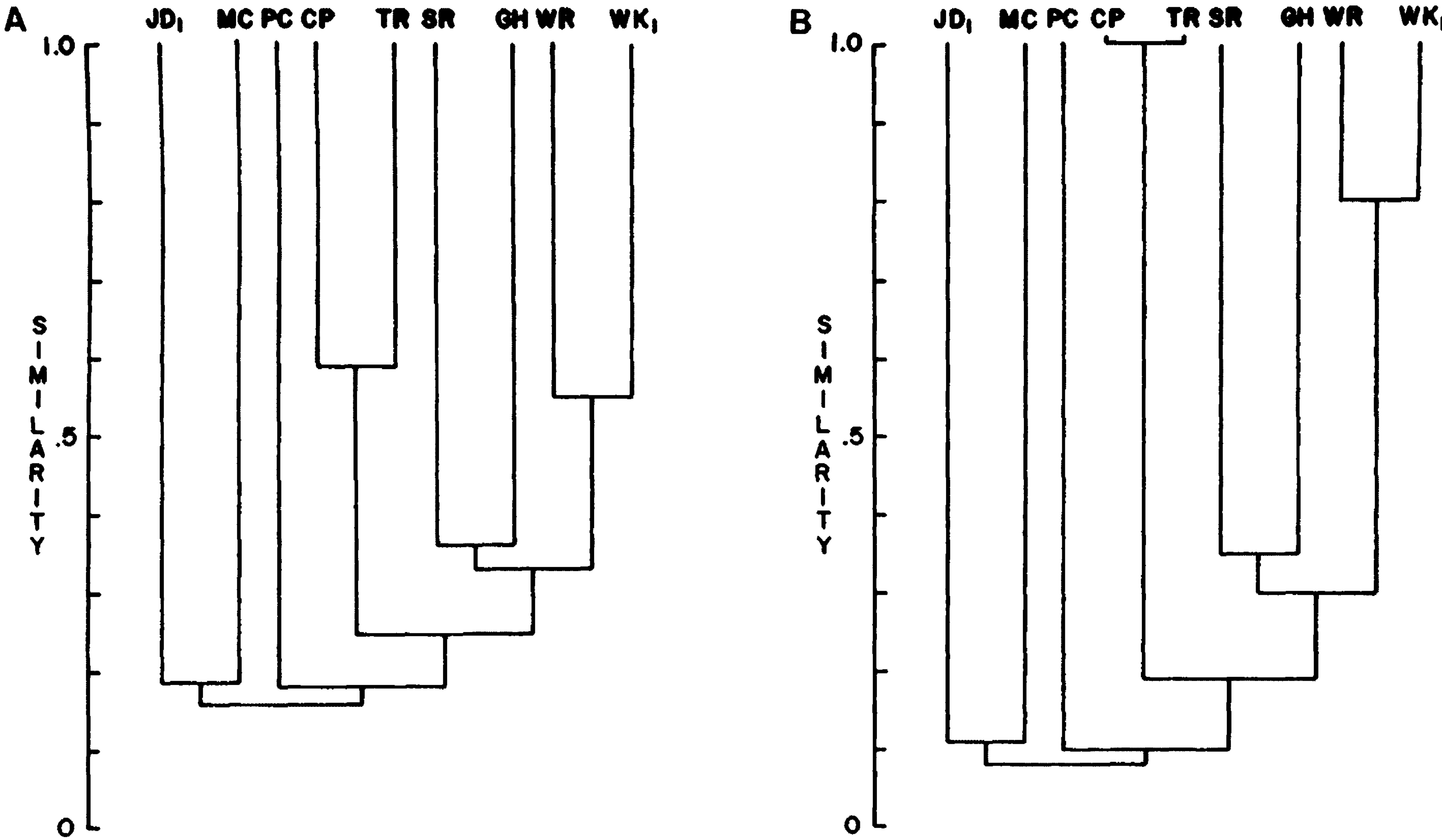

Figure 11. Dendrograms constructed in the cluster analysis of Early Arikareean rodent and oreodont genera. A, dendrogram based on Jaccard coefficient values, r_{mc}=0.86; B, dendrogram based on First Kulczynski coefficient values, r_{mc}=0.94.

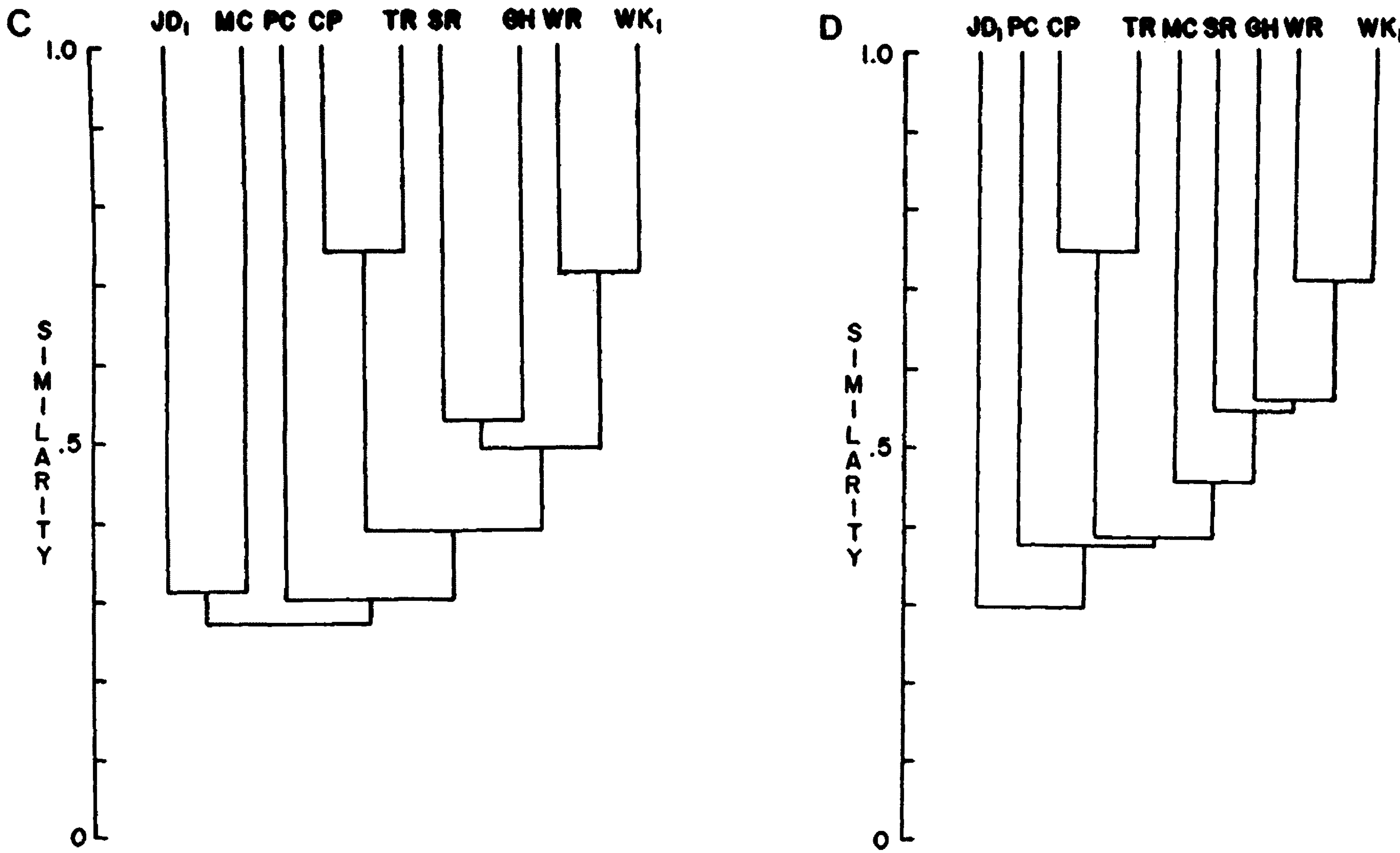

Figure 11. Continued. C, dendrogram based on Dice coefficient values, r_{mc}=0.82; D, dendrogram based on Second Kulczynski coefficient values, r_{mc}=0.76.

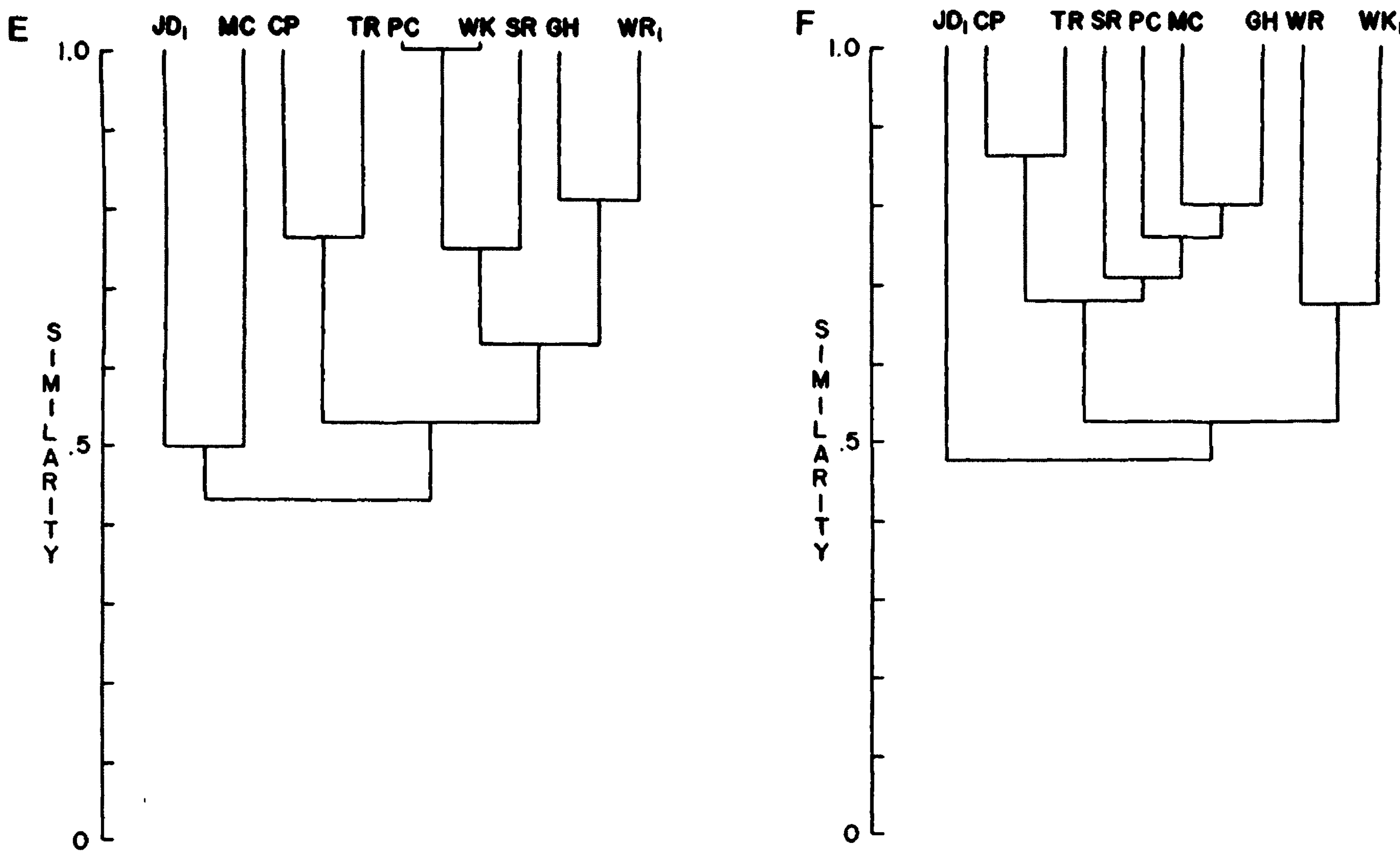

Figure 11. Continued. E, dendrogram based on Simpson coefficient values, r_{mc}=0.66; and F, dendrogram based on Simple Matching coefficient values, r_{mc}=0.90.

the Magpie Creek local fauna (MC), and the other group contains the remaining faunas.

The dendrograms based on Jaccard, First Kulczynski, and Dice coefficient values all show the same pattern (Fig. 11). Two main groups exist. One group contains the John Day fauna (JD_1) and the Magpie Creek local fauna (MC) and the other group contains the remaining faunas. The latter group consists of two subgroups. The first subgroup contains only the Peterson Creek local fauna (PC). The second subgroup is in turn subdivided into two groups:

1) the Cabbage Patch local faunas (CP) and the Tavenner Ranch local fauna (TR) form one group.
2) the Smith River fauna (SR), the Goshen Hole fauna (GH), the Wildcat Ridge fauna (WR), and the Wounded Knee fauna (WK_1) form the other group.

The dendrogram based on Second Kulczynski coefficient values shows a similar pattern to that of its counterpart in the cluster analysis involving all Early Arikareean mammalian genera (Fig. 11). The only difference is that the Magpie Creek local fauna (MC) and the Smith River fauna (SR) do not form a subgroup here; they branch off in this dendrogram separately.

The dendrogram based on Simpson coefficient values contains two major groups (Fig. 11). The first group contains the John Day fauna (JD_1) and the Magpie Creek local fauna (MC). The second group contains two subgroups:

1) the Cabbage Patch local faunas (CP) and the Tavenner Ranch local fauna (TR) form one subgroup.
2) the Peterson Creek local fauna (PC), the Wounded Knee fauna (WK_1), the Smith River fauna (SR), the Goshen Hole fauna (GH), and the Wildcat Ridge fauna (WR) form the other subgroup.

The dendrogram based on Simple Matching coefficient values contains two major groups (Fig. 11). The first group contains only the John Day fauna (JD_1). The second group is subdivided into two subgroups:

1) the Cabbage Patch local faunas (CP), the Tavenner Ranch local fauna (TR), the Smith River fauna (SR), the Peterson Creek local fauna (PC), the Magpie Creek local fauna (MC), and the Goshen Hole fauna (GH) form one subgroup.
2) the Wildcat Ridge fauna (WR) and Wounded Knee fauna (WK_1) form the other subgroup.

The cluster analysis of all Early Arikareean mammalian genera and Early Arikareean rodent and oreodont genera suggest that three faunal regions existed in the northwest during the Arikareean. These are the John Day region, the Montana-Idaho intermontane basin region, and the northern Great Plains region. The John Day region appears to be isolated from the other regions. The

Montana-Idaho intermontane basin region and the northern Great Plains region share the greatest similarity. Furthermore, the easternmost faunas of the Montana-Idaho intermontane basin region are closely associated with those of the northern Great Plains region. There also appears to be some faunal difference within the Montana-Idaho intermontane basin region (i.e. east vs. west).

Cluster analysis of all Early Arikareean mammalian genera in faunal groups- The next step in the cluster analysis of Early Arikareean mammalian genera was to analyze the faunal groups formed in the previous cluster analysis (i.e. the John day region, the Montana-Idaho intermontane basin region, and the northern Great Plains region). The Montana-Idaho intermontane basin region was subdivided into two regions. This was done to see if any differences within this region could be detected by this cluster analysis. The following abbreviations will be used: JD for the John Day fauna, WM for the western Montana fauna (this includes the only Idaho fauna), CM for the west-central Montana fauna, and GP for the northern Great Plains fauna.

The dendrograms generated in the cluster analysis of the Early Arikareean faunal groups, using all mammalian genera, are shown in Figure 12. It can be seen that three different dendrogram patterns exist (Fig. 12). The first

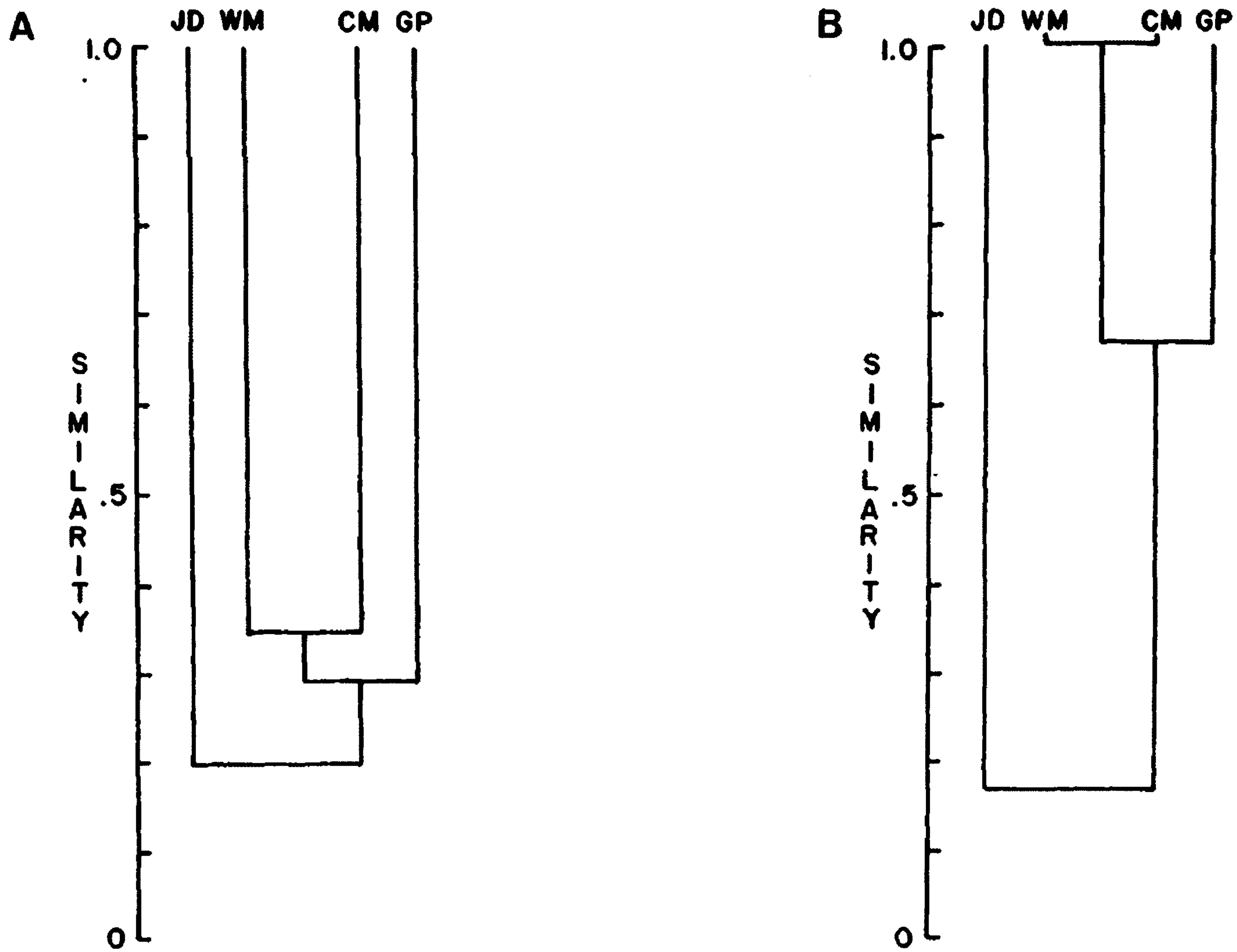

Figure 12. Dendrograms constructed in the cluster analysis of Early Arikareean faunal groups using all mammalian genera. A, dendrogram based on Jaccard coefficient values, r_{sc}=0.90; B, dendrogram based on First Kulczynski coefficient values, r_{sc}=0.92.

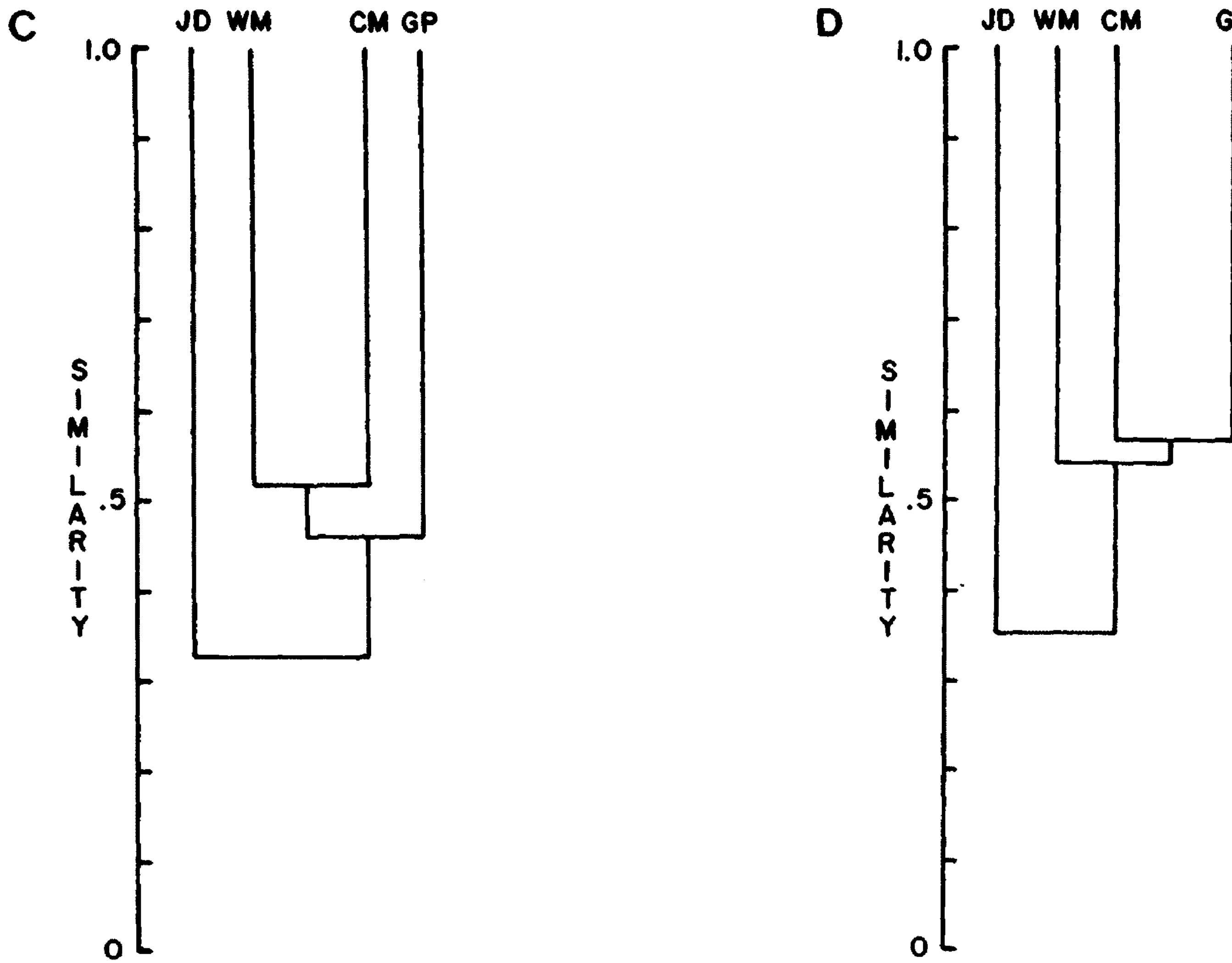

Figure 12. Continued. C, dendrogram based on Dice coefficient values, r_{mc}=0.89; D, dendrogram based on Second Kulczynski coefficient values, r_{mc}=0.91.

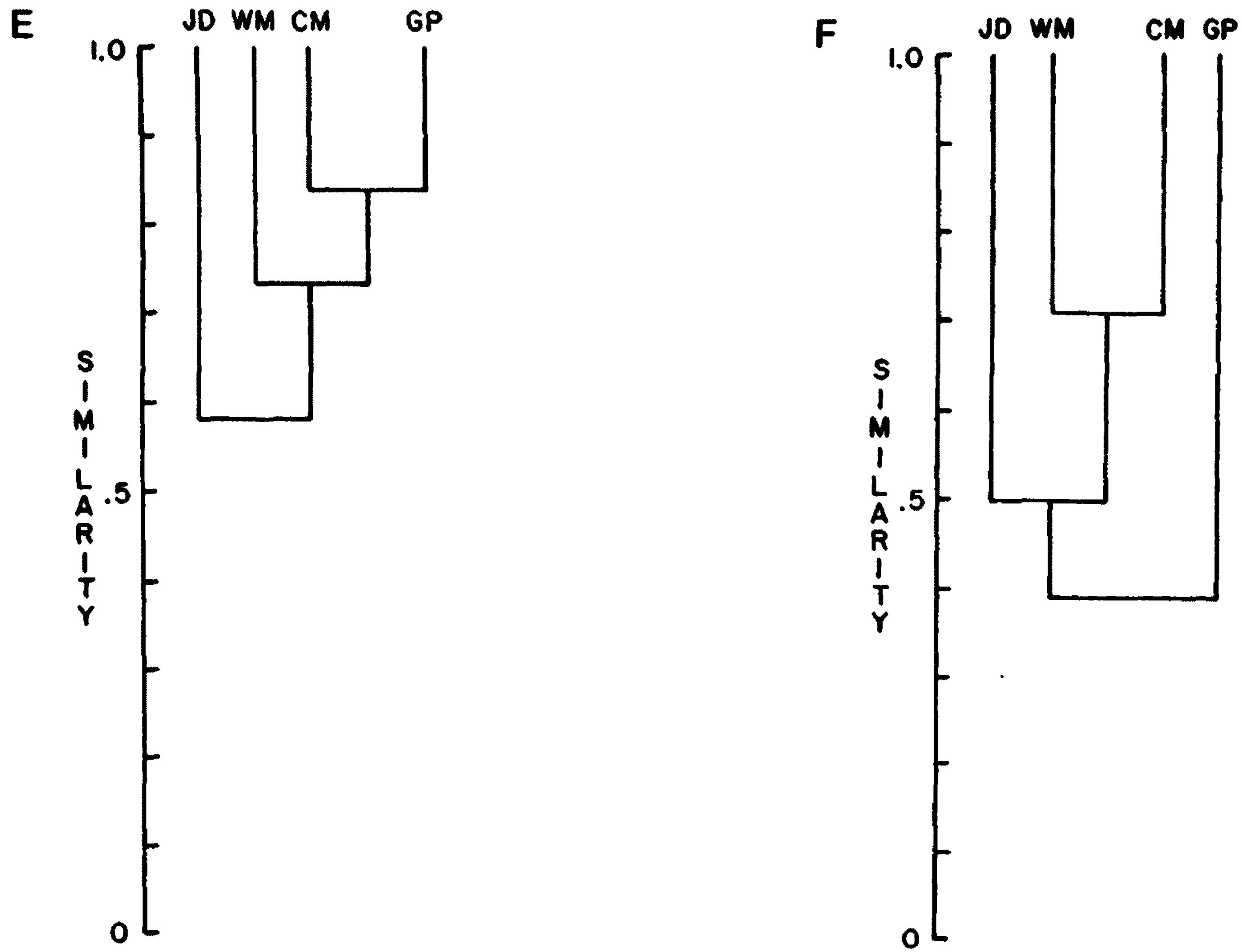

Figure 12. Continued. E, dendrogram based on Simpson coefficient values, r_{mc}=0.88; and F, dendrogram based on Simple Matching coefficient values, r_{mc}=0.92.

dendrogram is based on similarity coefficients that emphasize differences between faunas (i.e. Jaccard, First Kulczynski, and Dice coefficients) (Fig. 12). These dendrograms show the Montana faunas (WM and CM) forming a group with the most similarity. The northern Great Plains fauna (GP) then joins the Montana faunas (WM and CM) to form a larger group of faunal similarity. The John Day fauna (JD) has the lowest faunal similarity.

The second dendrogram is based on similarity coefficients that emphasize similarities between faunas (i.e. Second Kulczynski and Simpson coefficients) (Fig. 12). These dendrograms show the west-central Montana fauna (CM) and the northern Great Plains fauna (GP) forming a group with the most faunal similarity. The western Montana fauna (WM) then joins these two faunas to form a larger group of faunal similarity. The John Day fauna (JD) has the lowest faunal similarity in these dendrograms.

The third pattern of dendrograms is based on Simple Matching coefficient values (Fig. 12). This dendrogram shows the Montana faunas (WM and CM) forming a group with the most faunal similarity. The John Day fauna (JD) joins the Montana faunas to form a larger faunal group. The northern Great Plains fauna (GP) has the lowest faunal similarity in this dendrogram.

Cluster analysis of Early Arikareean rodent and

oreodont genera in faunal groups– The dendrograms generated in the cluster analysis of Early Arikareean faunal groups , using rodent and oreodont genera show two patterns (Fig 13). The first dendrogram pattern is based on similarity coefficients that emphasize differences and similarities between faunas (Fig. 13). These dendrograms show the west-central Montana fauna (CM) and the northern Great Plains fauna (GP) forming a group with the most faunal similarity. The western Montana fauna (WM) joins these two faunas to form a larger faunal group. The John Day fauna (JD) has the lowest faunal similarity.

The second dendrogram pattern is based on Simple Matching coefficient values (Fig. 13). This dendrogram shows the Montana faunas forming a group with the most faunal similarity. The northern Great Plains fauna (GP) joins the Montana faunas (WM and CM) to form a larger faunal group. The John Day fauna (JD) has the lowest faunal similarity in this dendrogram.

The cluster analysis of the Early Arikareean faunal groups shows that there are some faunal differences within the Montana-Idaho intermontane basin region and that the Montana-Idaho intermontane basin and the northern Great Plains regions share the greatest similarity. The John Day region is the most isolated region.

Cluster analysis of all Late Arikareean mammalian

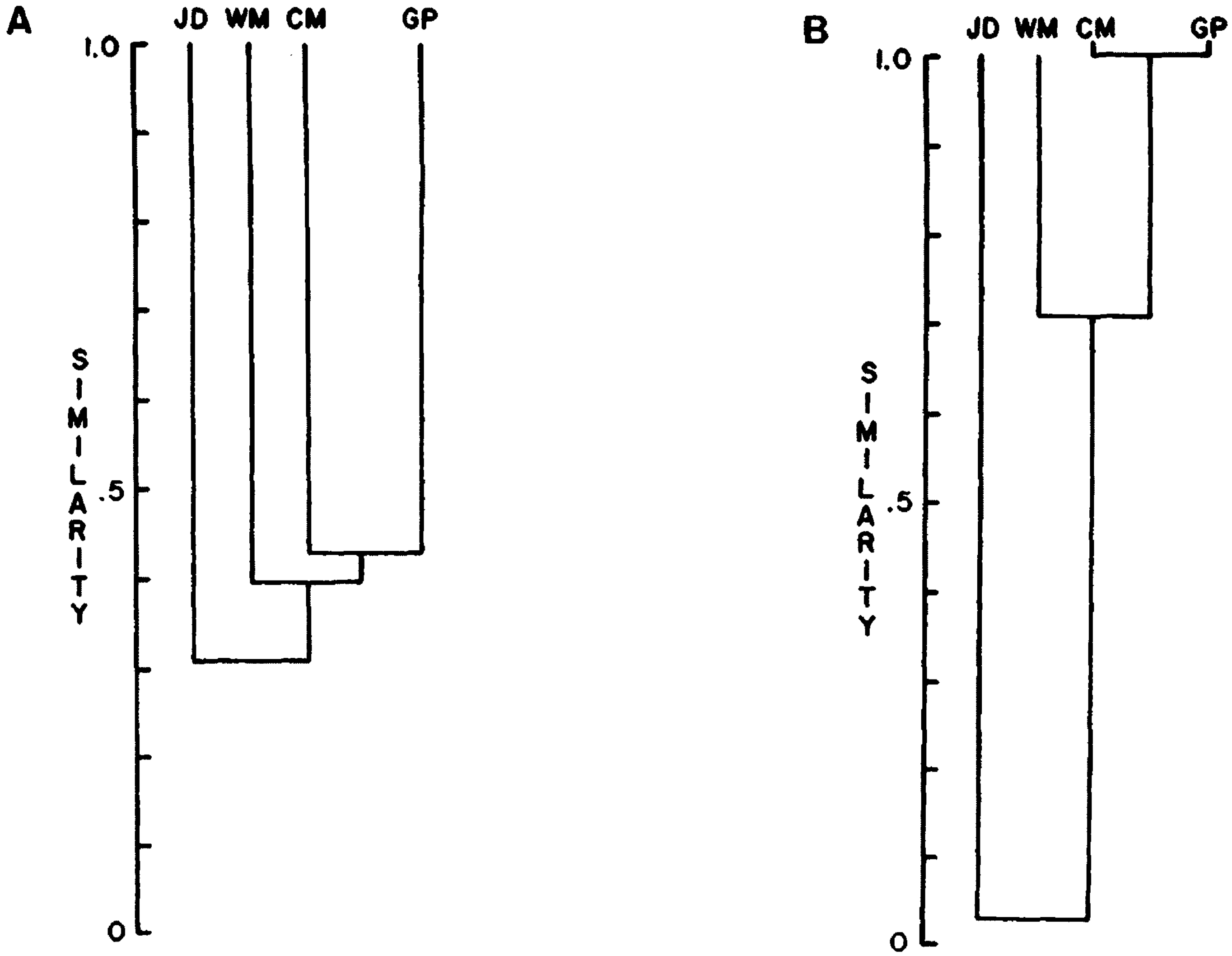

Figure 13. Dendrograms constructed in the cluster analysis of Early Arikareean faunal groups using rodent and oreodont genera. A, dendrogram based on Jaccard coefficient values, r_{ec}=0.99; B, dendrogram based on First Kulczynski coefficient values, r_{ec}=0.99.

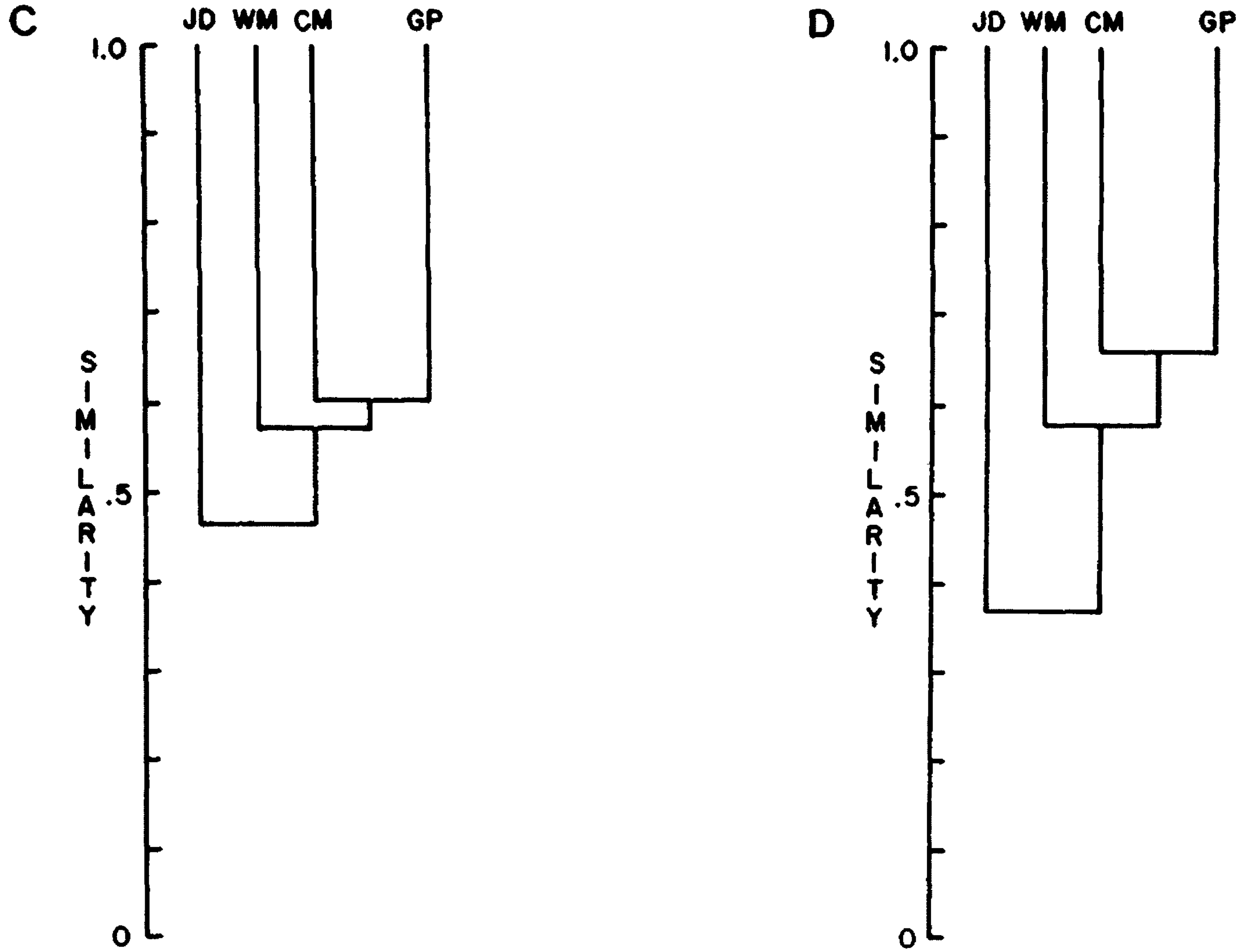

Figure 13. Continued. C, dendrogram based on Dice coefficient values, r_{mc}=0.97; D, dendrogram based on Second Kulczynski coefficient values, r_{mc}=0.99.

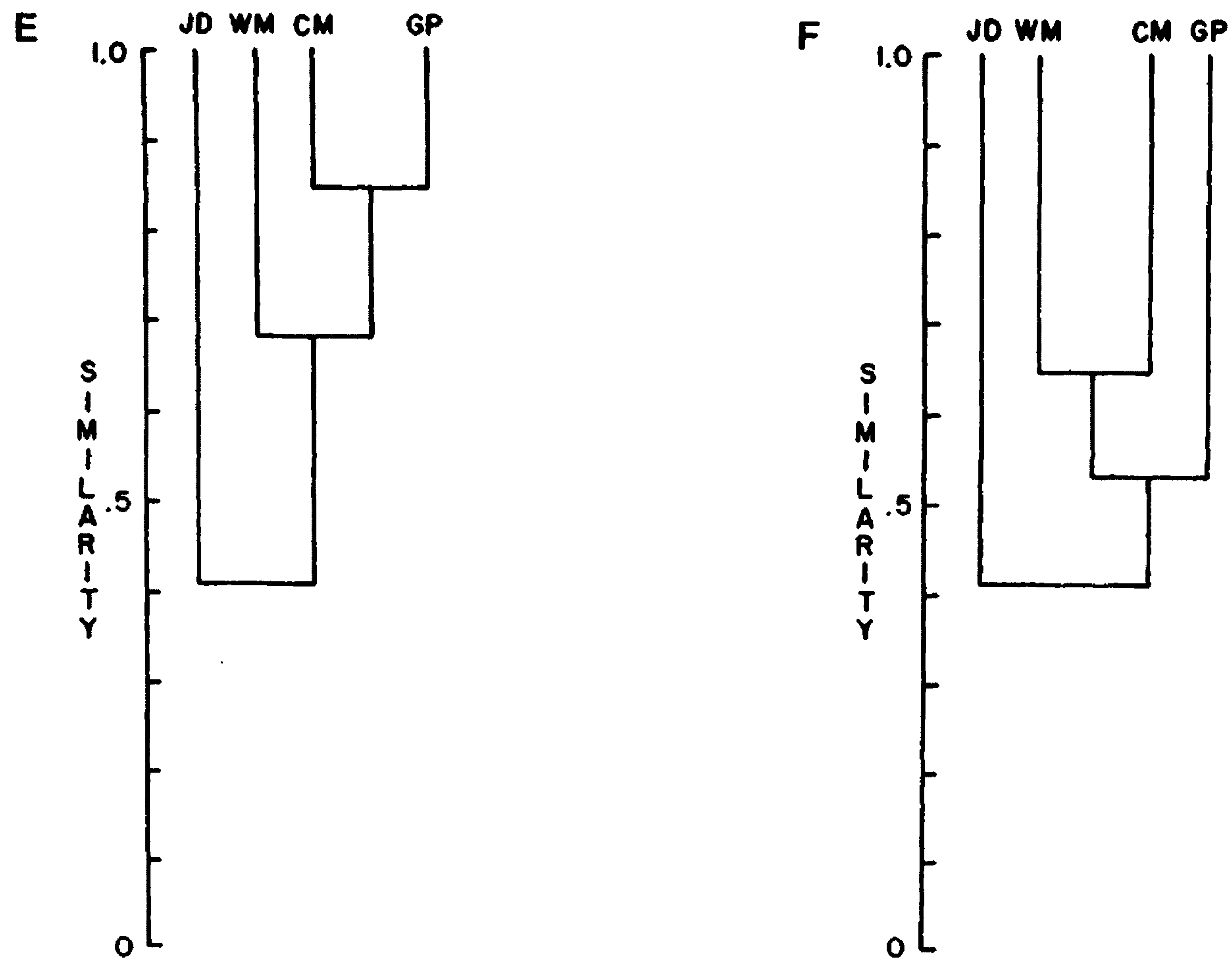

Figure 13. E, dendrogram based on Simpson coefficient values, $r_{mc}=0.91$; and F, dendrogram based on Simple Matching coefficient values, $r_{mc}=0.76$.

genera- The dendrograms generated in the cluster analysis of all Late Arikareean mammalian genera show three patterns (Fig. 14). The first dendrogram pattern is based on similarity coefficients that emphasize differences between faunas (i.e. Jaccard, First Kulczynski, and Dice coefficients) (Fig. 14). These dendrograms show the western Nebraska composite fauna (WN) and the Wounded Knee fauna (WK_{2}) forming the group with the most similarity. The John Day fauna (JD_{2}) is then grouped with these two faunas to form a larger group. The Negro Hollow local fauna (NH) is shown to have the lowest faunal similarity.

The second dendrogram pattern is based on Second Kulczynski and Simple Matching coefficient values (Fig. 14). These dendrograms show the western Nebraska composite fauna (WN) and the Wounded Knee fauna (WK_{2}) forming the group with the most similarity. The Negro Hollow local fauna (NH) is then grouped with these two faunas, forming a larger group of similarity. The John Day fauna (JD_{2}) appears to have the lowest faunal similarity.

The third dendrogram pattern is based on Simpson coefficient values (Fig. 14). This dendrogram shows the Negro Hollow local fauna (NH) and the western Nebraska composite fauna (WN) forming the group with the most similarity. The Wounded Knee fauna (WK_{2}) is then grouped with these two faunas, forming a larger group of

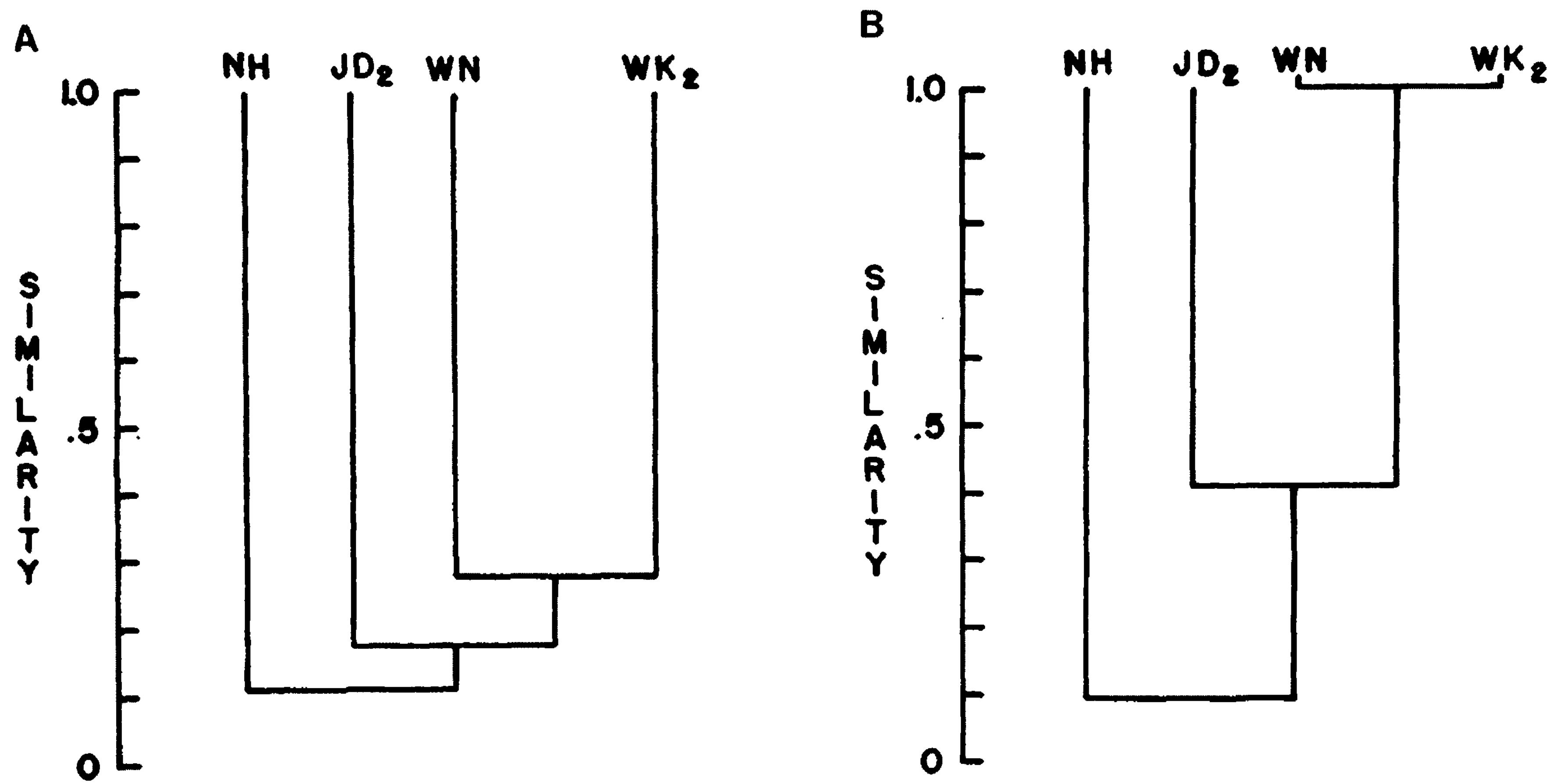

Figure 14. Dendrograms constructed in the cluster analysis of all Late Arikareean mammalian genera. A, dendrogram based on Jaccard coefficient values, r_{sc}=0.92; B, dendrogram based on First Kulczynski coefficient values, r_{sc}=0.93.

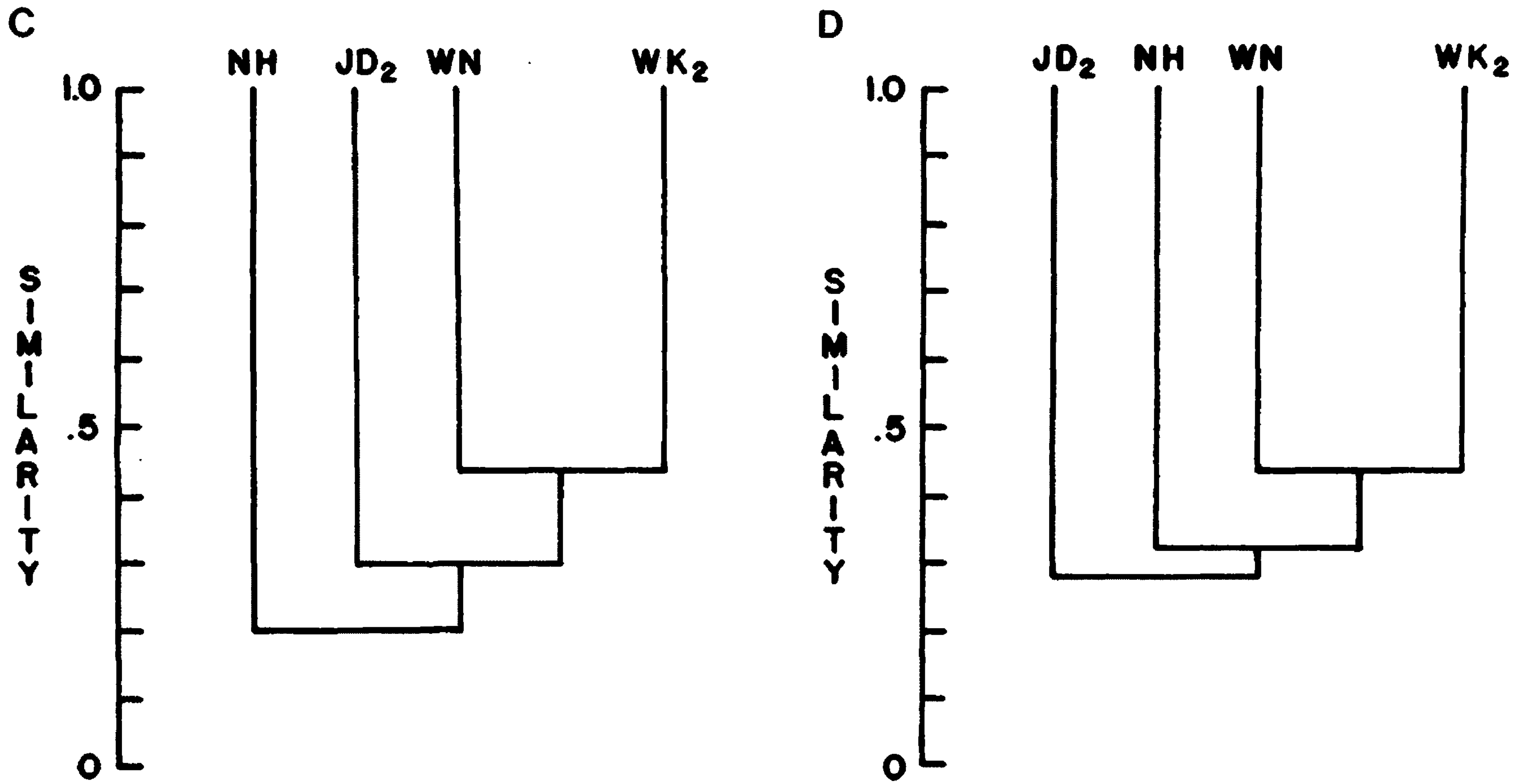

Figure 14. Continued. C, dendrogram based on Dice coefficient values, r_{mc}=0.91; D, dendrogram based on Second Kulczynski coefficient values, r_{mc}=0.76.

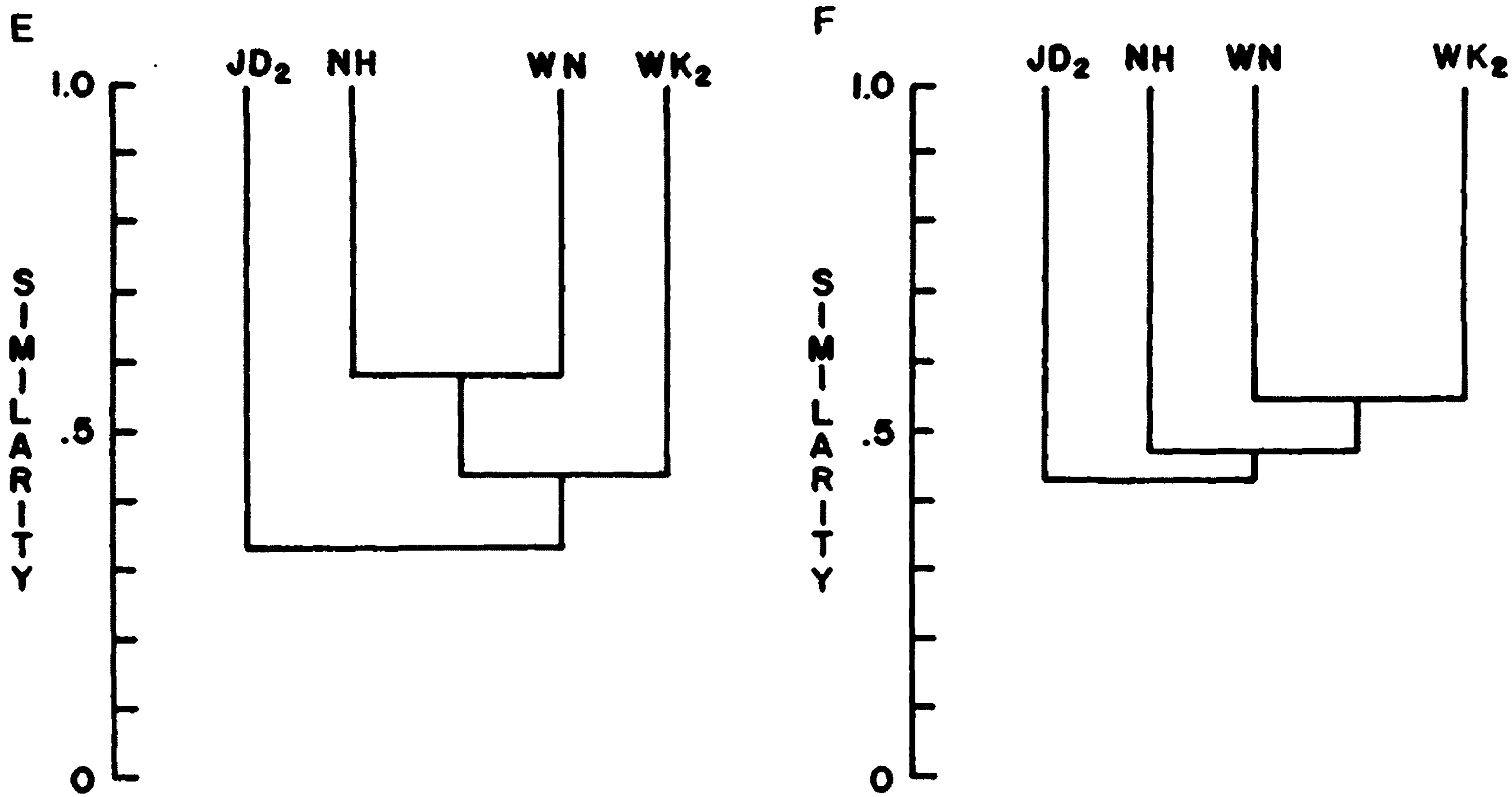

Figure 14. Continued. E, dendrogram based on Simpson coefficient values, r_{mc}=0.94; and F, dendrogram based on Simple Matching coefficient values, r_{mc}=0.56.

similarity. The John Day fauna (JD_e) has the lowest faunal similarity.

Cluster analysis of Late Arikareean perissodactyl and artiodactyl genera– The dendrograms generated in the cluster analysis of Late Arikareean perissodactyl and artiodactyl genera show two patterns (Fig. 15). The first dendrogram pattern is based on similarity coefficients that emphasize differences between faunas (i.e. Jaccard, First Kulczynski, and Dice coefficients), and Second Kulczynski coefficient values (Fig. 15). These dendrograms show the western Nebraska composite fauna (WN) and the Wounded Knee fauna (WK_e) forming a group with the most faunal similarity. The John Day fauna (JD_e) is then grouped with these two faunas, forming a larger group of faunal similarity. The Negro Hollow local fauna (NH) appears to have the lowest faunal similarity.

The second dendrogram pattern is based on Simpson and Simple Matching coefficient values (Fig. 15). These dendrograms show the western Nebraska composite fauna (WN) and the Wounded Knee fauna (WK_e) forming a group with the most faunal similarity. The Negro Hollow local fauna (NH) is then grouped with these two faunas to form a larger group of faunal similarity. The John Day fauna (JD_e) has as the lowest faunal similarity.

As mentioned in the Methods section, caution must be

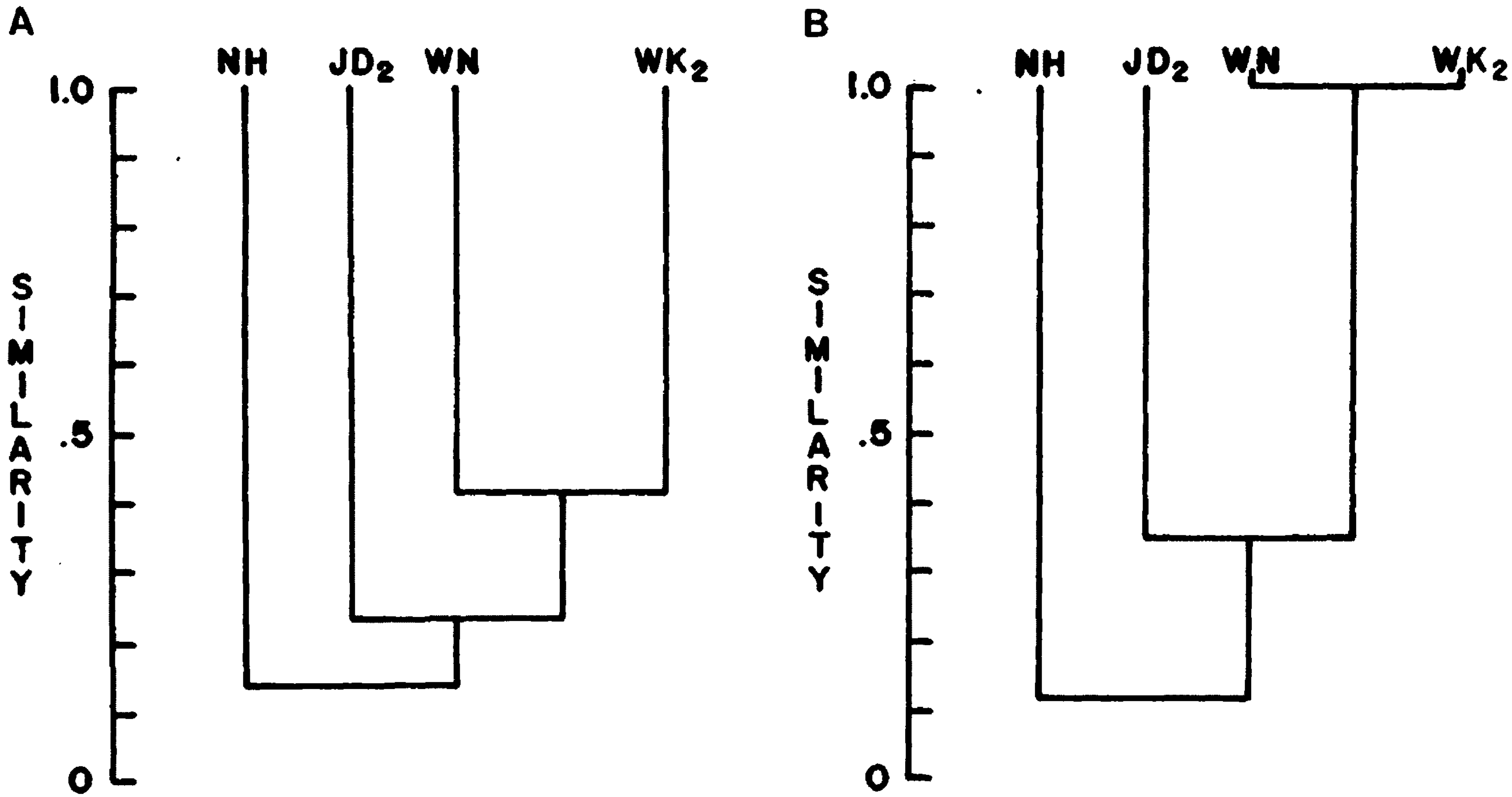

Figure 15. Dendrograms constructed in the cluster analysis of Late Arikareean perissodactyl and artiodactyl genera. A, dendrogram based on Jaccard coefficient values, r_{mc}=0.94; B, dendrogram based on First Kulczynski coefficient values, r_{mc}=0.97.

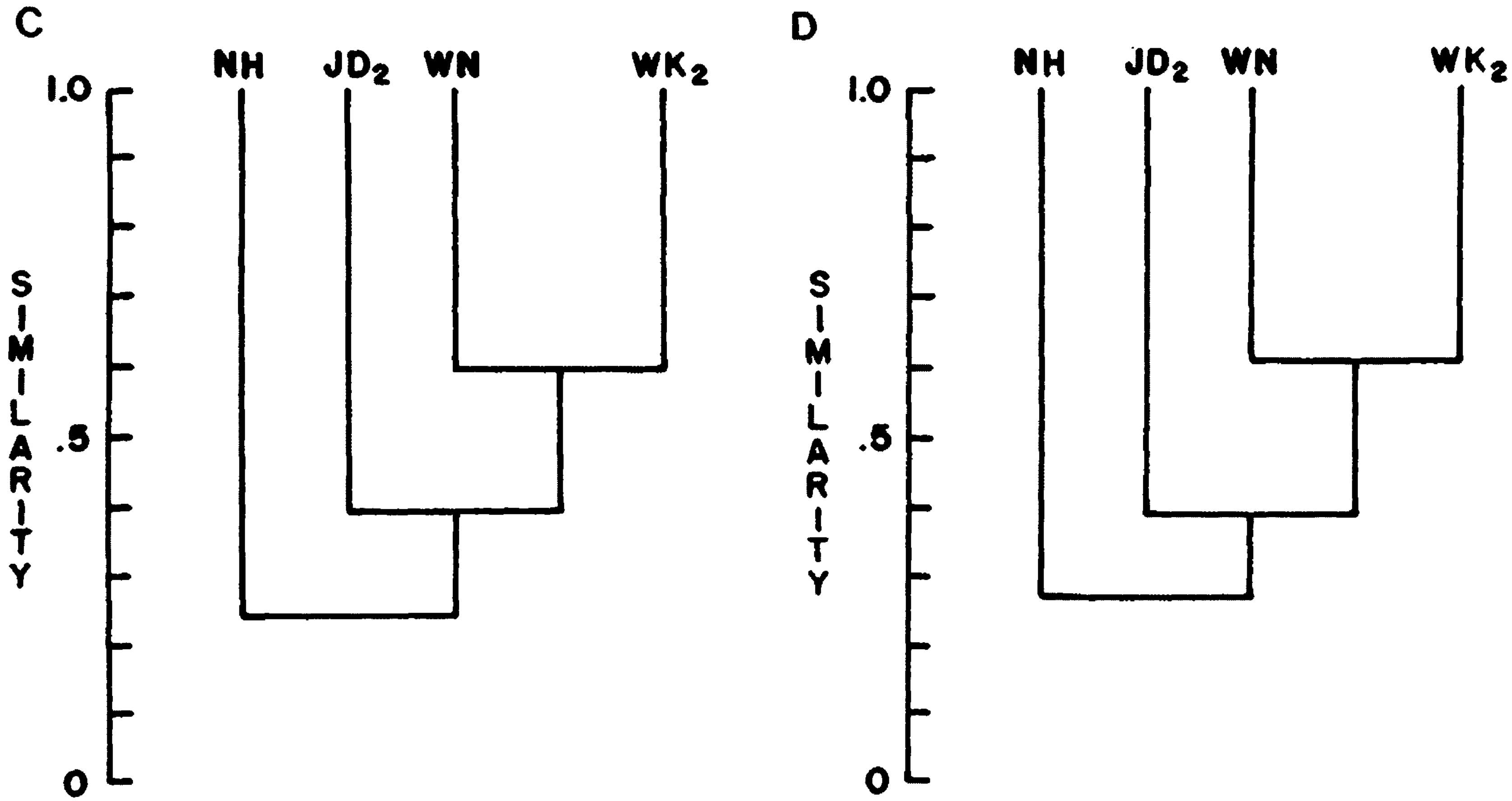

Figure 15. Continued. C, dendrogram based on Dice coefficient values, r_{mc}=0.92; D, dendrogram based on Second Kulczynski coefficient values, r_{mc}=0.87.

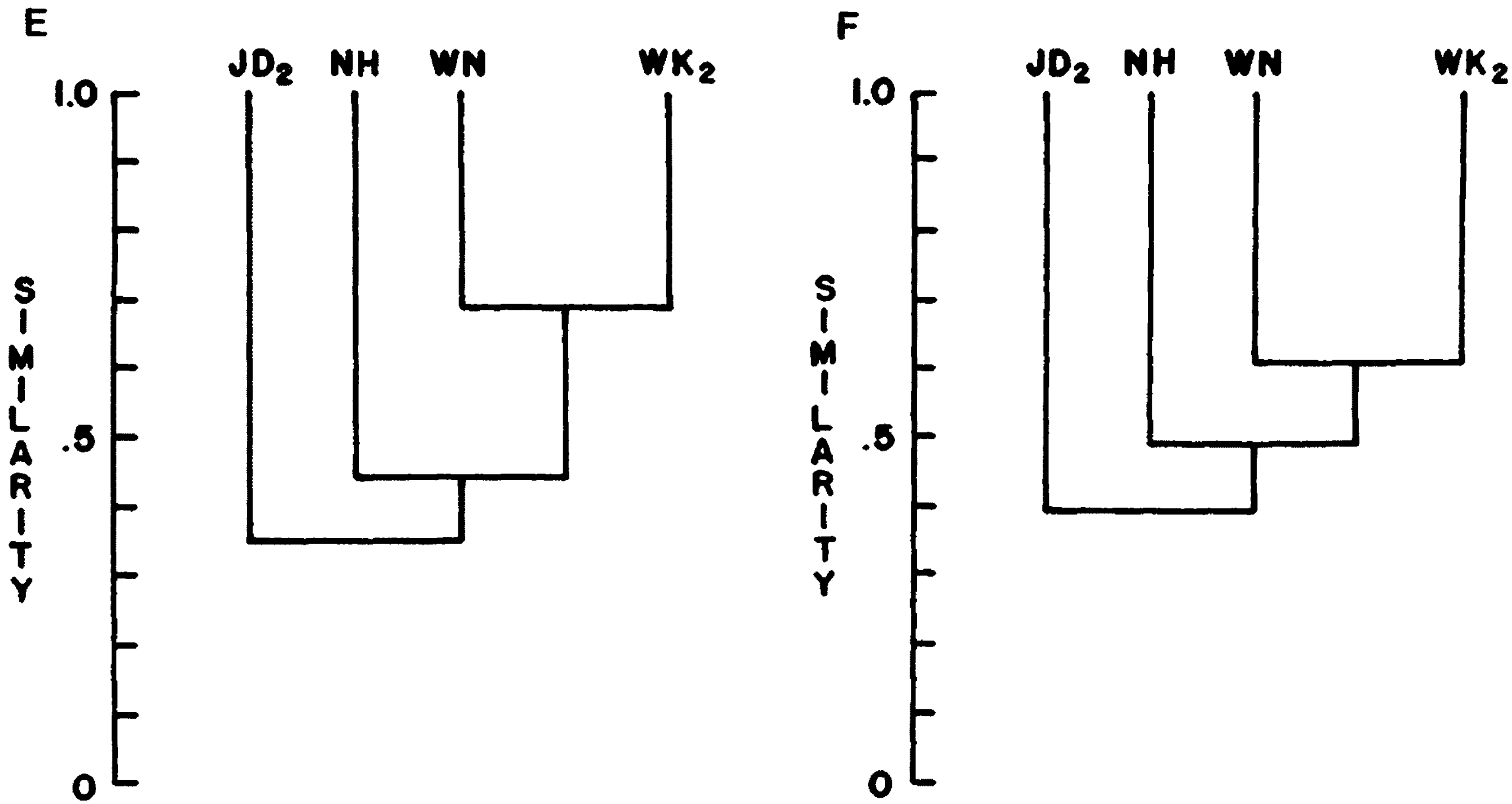

Figure 15. Continued. E, dendrogram based on Simpson coefficient values, $r_{s}C$=0.79; and F, dendrogram based on Simple Matching coefficient values, r_{sc}=0.88.

taken in interpreting Late Arikareean data. However, it appears that three regions of faunal similarity identified in the cluster analysis of Early Arikareean data also existed during the Late Arikareean. Also, dispersal was taking place between these regions, but the extent of this dispersal cannot be estimated until more data is available.

Gradient Changes

Changes in the gradient of similarity values across an area where one fauna is compared to the others may reveal boundaries between regions (Flynn, 1986). Many examples of gradient changes were observed. Here, I have shown a few representative examples (Fig. 16). The gradient changes seen here show that there were boundaries between the three regions. A sharp gradient change is seen between the John Day and Montana-Idaho intermontane basin regions. Minor gradient changes are seen within the Montana-Idaho intermontane basin region and between the Montana-Idaho intermontane basin region and the northern Great Plains region.

A

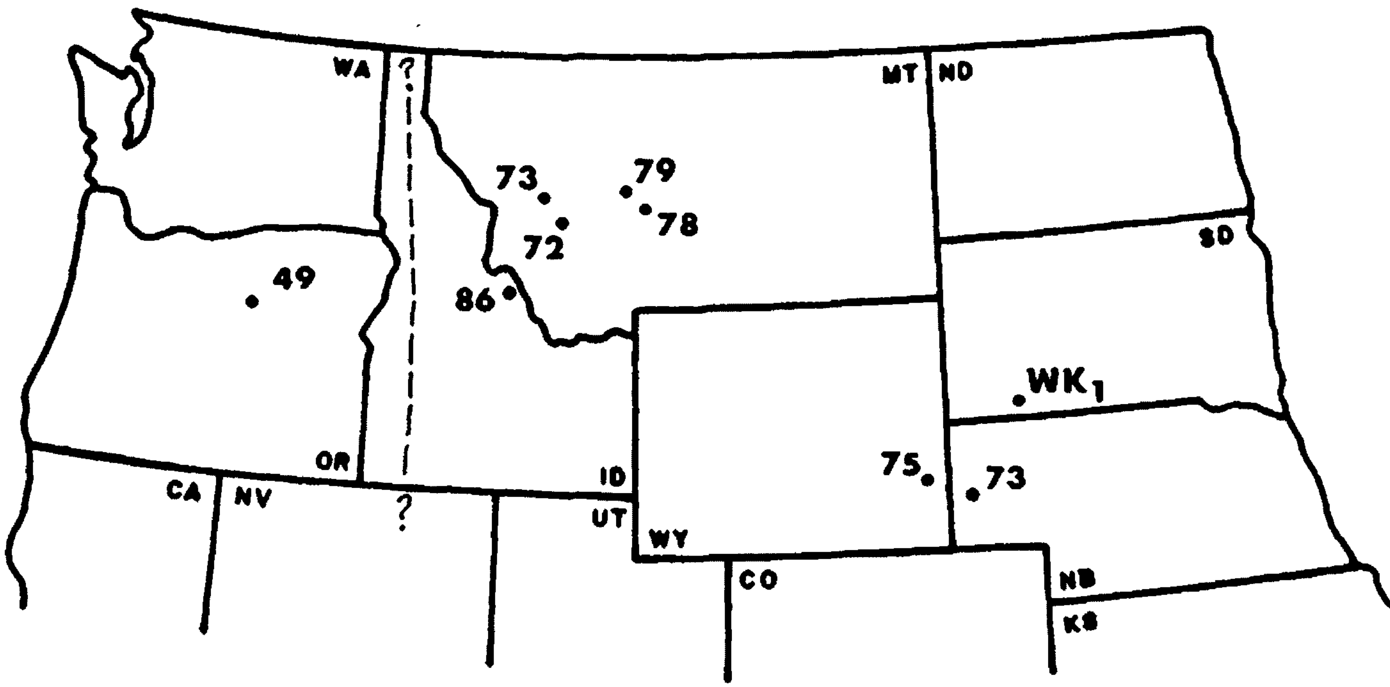

Figure 16. Gradient changes seen in faunal similarity values, which indicate boundaries between regions. A, gradient changes seen in Simpson coefficient values when the Wounded Knee fauna (WK_1) is compared to the other faunas.

B

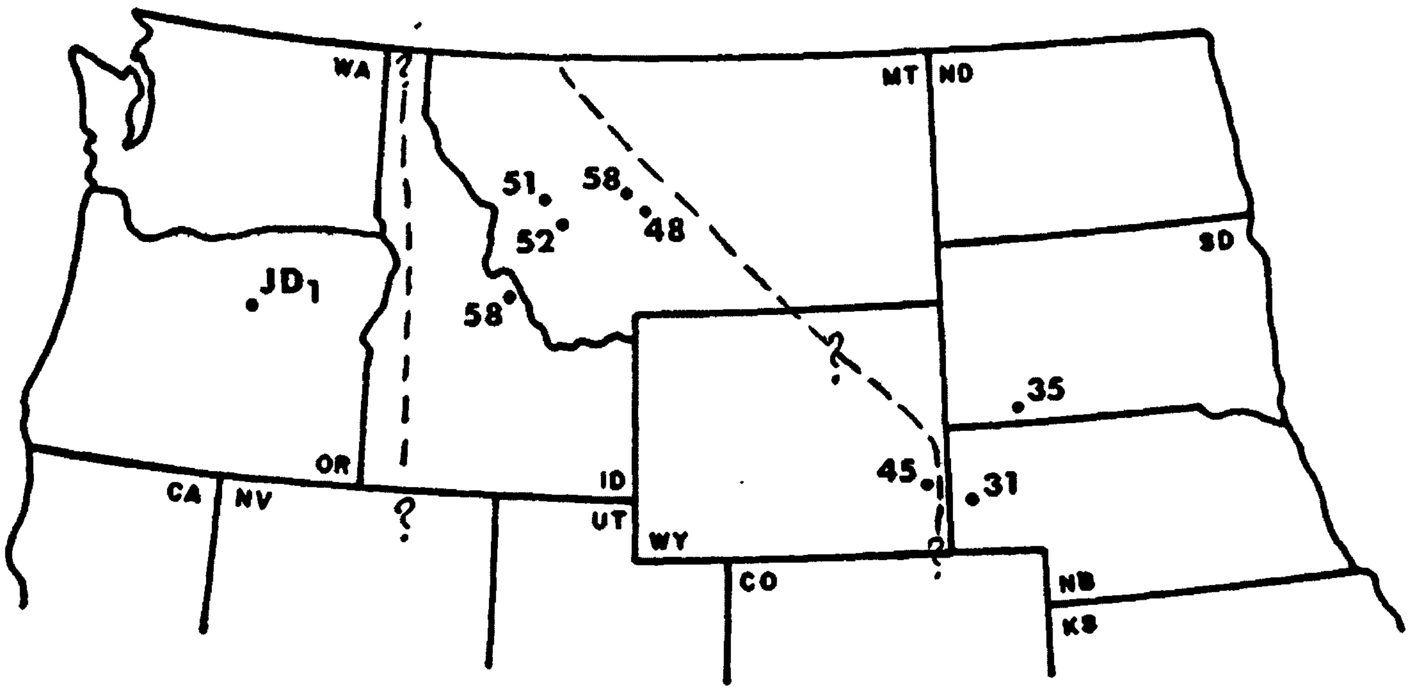

Figure 16. Continued. B, gradient changes seen in Simple Matching coefficient values when the John Day fauna (JD_1) is compared to the other faunas.

INTERPRETATIONS AND CONCLUSIONS

The results of the observational and cluster analyses of Early and Late Arikareean faunas within the northwest region of the United States has revealed that three regions of faunal similarity were present. Since each region is characterized by several genera (see Tables 1 and 4), they can be referred to as faunal provinces. Throughout the rest of this paper, I will refer to each region as a faunal province. The names I propose for these faunal provinces are as follows:

1) the John Day Faunal Province (=John Day region)
2) the Intermontane Basin Faunal Province (=Montana-Idaho intermontane basin region)
3) the Northern Platte River-Wounded Knee Faunal Province (=Northern Great Plains region).

The following interpretations are based on the results of the observational and cluster analyses of Early and Late Arikareean faunas:

1) the John Day Faunal Province was the most isolated of the faunal provinces. It shares the least in common with the other faunal provinces and is separated from the other faunal provinces by a major geographical barrier (i.e. the Idaho batholith).

2) the Intermontane Basin Faunal Province and the North Platte River-Wounded Knee Faunal Province share the greatest similarity.

3) one major barrier existed in the northwest region, which was between the John Day Faunal Province and the Intermontane Faunal Province. This major boundary corresponds to the Idaho batholith area.

4) two minor barriers existed in the northwest region. The first is between the Intermontane Basin Faunal Province and the North Platte River-Wounded Knee Faunal Province, which corresponds to the Front Ranges of the Rocky Mountains. The second barrier occurs within the Intermontane Basin Faunal Province, which may either correspond to the continental divide at that time or may be a response to distance from the North Platte River-Wounded Knee Faunal Province.

5) it appears as if the Intermontane Basin Faunal Province acted as a filter zone for east-west and west-east dispersing populations. This is especially true for west-east dispersing populations. Mammals that could not disperse through this filter zone (for ecological or geographical reasons) may have dispersed to the south. This may explain the presence of disjunct

John Day F.P.	Intermontane Basin F.P.	N. Platte River-Wounded Knee F.P.
Early Arikareean	Early Arikareean	Late Arikareean
<-------	Promerycochoerus --------->	-------------->
Early Arikareean	Late Arikareean	Late Arikareean
<-- Hypsiops -->	-------------->	-------------->
<-- Cynorca -->	?	-------------->
<-- Moropus -->	?	-------------->
Early Arikareean	Late Arikareean	Early Arikareean
Anchitherium ----------->	<-----------	Anchitherium
Oxydactylus ------------>	<------------	Oxydactylus
	<------------------------	Dinohyus
	<--------------------	Nanotragulus

Figure 17. Dispersal through time (during the Arikareean).

genera (genera endemic to the John Day Faunal Province and the North Platte River-Wounded Knee Faunal Province in this case).

6) this filter zone probably imposed more of a geographical barrier than an ecological barrier, since the entire northwest region was semi-arid to arid. The major barrier separating the John Day Faunal Province and the Intermontane Basin Faunal Province may account for the similarity between the Intermontane Basin Faunal Province and the North Plate River-Wounded Knee Faunal Province. The apparent isolation of the John Day Faunal Province is probably a reflection of a geographic isolation. Thus, the distributions of these mammals is probably governed by geography.

Examples of dispersal through time (i.e. during the Arikareean) are seen here (Figure 17). However, these examples must be treated as tentative, considering the nature of the fossil record in Montana and for the Late Arikareean.

Cluster analysis of faunal similarity data can serve as an objective means to determine relationships between faunas. Several similarity coefficients should be used to avoid biasing the results and to average out the different results obtained from the various similarity coefficients.

Also, cluster analysis is a good way to confirm or reject existing observations of faunal relationships.

One of the purpose of this study was to prompt similar studies of this nature. I believe that I have shown that this method of analysis is useful in determining the relationships between faunas. Cluster analysis is a useful tool in bioassociational (i.e. faunal similarity) analysis. I feel that there are enough stratigraphic and fossil data available for studies of this nature.

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LITERATURE CITED

Barnosky, A. D. 1984. The Colter Formation: Evidence for Miocene volcanism in Jackson Hole, Teton County, Wyoming. Wyoming Geological Association of Earth Sciences Bulletin 17:49-98.

______. 1986. Arikareean, Hemingfordian, and Barstovian mammals from the Miocene Colter Formation, Jackson Hole, Teton County, Wyoming. Bulletin of Carnegie Museum of Natural History 26:1-69.

Barshad, I. 1966. The effect of a variation in precipitation on the nature of clay mineral formation in soils from acid and basic igneous rocks. The Clay Mineralogy Society, Proceedings of the International Clay Conference, Jerusalem, Volume 1.

Black, C. C. 1961. Rodents and lagomorphs from the Miocene Fort Logan and Deep River Formations of Montana. Postilla 48:1-20.

______. 1963. A review of the North American Tertiary Sciuridae. Bulletin of the Museum of Comparative Zoology, Harvard University 130:109-248.

Brown, J. H., and Gibson, A. C. 1983. Biogeography. The C. V. Mosby Company, St. Louis, 643 p.

Cheetham, A. H., and Hazel, J. E. 1969. Binary (presence-absence) similarity coefficients. Journal of Paleontology 43:1130-1136.

Coombs, M. C. 1978. Reevaluation of early Miocene North American <u>Moropus</u> (Perissodactyla, Chalicotheriidae, Schizotheriinae). Bulletin of Carnegie Museum of Natural History 4:1-62.

Dawson, M. R. 1958. Later Tertiary Leporidae of North America. University of Kansas Paleontological Contributions, Vertebrata 6:1-75.

Fallaw, W. C. 1979. A test of the Simpson Coefficient and other binary coefficients of faunal similarity. Journal of Paleontology 53:1029-1034.

Farris, J. S. 1969. On the cophenetic correlation coefficient. Systematic Zoology 18:279-285.

Fields, R. W., Rasmussen, D. L., Tabrum, A. R., and Nichols, R. 1985. Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho: a summary, p. 9-36. In Flores, R. M., and Kaplan, S. S. (eds.), Rocky Mountain Paleogeographic Symposium 3, Cenozoic paleogeography of west-central United States. Denver, Colorado, The Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists.

Fisher, R. V. and Rensberger, J. M. 1972. Physical stratigraphy of the John Day Formation, central Oregon. University of California, Publications in Geological Sciences 101:1-33.

Flessa, K. W. 1981. The regulation of mammalian faunal similarity among the continents. Journal of Biogeography 8:427-438.

Flynn, J. J. 1986. Faunal provinces and the Simpson Coefficient. In Flanagan, F. M., and Lillegraven, J. A. (eds.) Vertebrates, phylogeny, and philosophy. Contributions to Geology, University of Wyoming, Special Paper 3:317-338.

Frick, C. 1937. Horned ruminants of North America. Bulletin of the American Museum of Natural History 69:1-669.

Frick, C., and Taylor, B. E. 1971. Michenia, a new protolabine (Mammalia, Camelidae) and a brief review of the early taxonomic history of the genus Protolabis. American Museum Novitates 2444:1-24.

Green, M. 1956. A review of the stratigraphy and vertebrate paleontology of the John Day Formation. Unpublished Ph.D. dissertation, University of California, Berkeley, California, 188 p.

______. 1972. Lagomorphs from the Rosebud Formation, South Dakota. Journal of Paleontology 46:377-385.

______. 1977. Neogene Zapodidae (Mammalia: Rodentia) from South Dakota. Journal of Paleontology 51:996-1015.

Green, M., and Martin, J. E. 1976. Peratherium (Marsupialia: Didelphidae) from the Oligocene and Miocene of South Dakota, p. 155-168. In Churcher, C. S. (ed.), Athlon: Essays on palaeontology in honour of Loris Shano Russell. Royal Ontario Museum, Life Sciences Miscellaneous Publications.

Hunt, R. M. 1981. Geology and vertebrate paleontology of the Agate Fossil Beds National Monument and surrounding region, Sioux County, Nebraska (1972-1978). National Geographic Society Research Reports 13:263-285.

_____, R. M. 1985. Faunal succession, lithofacies, and depositional environments in Arikaree rocks (lower Miocene) of the Hartville Table, Nebraska and Wyoming. In Martin, J. E. (ed.), Fossiliferous Cenozoic deposits of western South Dakota and northwestern Nebraska. Dakoterra 2:155-204.

Hutchison, J. H. 1972. Review of the Insectivora from the early Miocene Sharps Formation of South Dakota. Contributions in Science, Natural History Museum of Los Angeles County 235:1-16.

Keller, W. D. 1965. The principles of chemical weathering. Columbia, Missouri, Lucas Brothers Publishers, 111 p.

Koerner, H. E. 1939. The geology and vertebrate paleontology of the Fort Logan and Deep River Formations of Montana. Unpublished Ph.D. dissertation, Yale University, New Haven, Connecticut, 141 p.

_____. 1940. The geology and vertebrate paleontology of the Fort Logan and Deep River Formations of Montana. Part 1, new vertebrates. American Journal of Science 238:837-862.

Lofgren, D. L. 1985. Tertiary vertebrate paleontology, stratigraphy, and structure, North Boulder river basin, Jefferson County, Montana. Unpublished M.S. thesis, University of Montana, Missoula, Montana, 113 p.

Loope, D. B. 1986. Recognizing and utilizing vertebrate tracks in cross section: Cenozoic hoofprints from Nebraska. Palaios 1:141-151.

MacDonald, J. R. 1963. The Miocene faunas from the Wounded Knee area of western South Dakota. Bulletin of the American Museum of Natural History 125:141-238.

_____. 1970. Review of the Miocene Wounded Knee faunas of southwestern South Dakota. Bulletin Los Angeles County Museum of Natural History, Science 8:1-82.

MacDonald, L. J. 1972. Monroe Creek (early Miocene) microfossils from the Wounded Knee area, South Dakota. South Dakota Geological Survey, Report of Investigations no. 105, 43 p.

Martin, L. D. 1973. The mammalian fauna of the lower Miocene Gering Formation of western Nebraska and the early evolution of the North American Cricetidae. Unpublished Ph.D. dissertation, University of Kansas, Lawrence, Kansas, 264 p.

______. 1974. New rodents from the lower Miocene Gering Formation of western Nebraska. Occasional Papers, Museum of Natural History, University of Kansas 32: 1-12.

Matthew, W. D. 1909. Cenozoic mammal horizons of western North America. United States Geological Survey Bulletin 361:1-138.

______. 1926. On a new primitive deer and two traguloid genera from the lower Miocene of Nebraska. American Museum Novitates 215:1-8.

McGrew, P. O. 1937. New marsupials from the Tertiary of Nebraska. Journal of Geology 45:448-455.

______. 1941. A new Miocene lagomorph. Field Museum of Natural History, Geological Series 8:37-41.

McKenna, M. C., and Love, J. D. 1972. High-level strata containing early Miocene mammals of the Bighorn Mountains, Wyoming. American Museum Novitates 2490:1-31.

Merriam, J. C., and Sinclair, W. J. 1907. Tertiary faunas of the John Day region. University of California Publications, Bulletin of the Department of Geology 5:171-205.

Nichols, R. 1976. Early Miocene mammals from the Lemhi valley of Idaho. Tebiwa 18:9-47.

______. 1979. Additional early Miocene mammals from the Lemhi valley of Idaho. Idaho State University Museum of Natural History, Miscellaneous Papers 17:1-12.

Nilsen, T. H., and McKee, E. H. 1979. Paleogene paleogeography of the western United States, in Armentrout, J. M., ed., Pacific Coast Paleogeography Symposium No. 3, Cenozoic paleogeography of the western United States, p. 257-276.

Orr, W. N., and Orr, E. L. 1981. Handbook of Oregon plant and animal fossils. Eugene, Oregon, William N. Orr, 285 p.

Patton, T. H., and Taylor, B. E. 1971. The Synthetoceratinae (Mammalia, Tylopoda, Protoceratidae). Bulletin of the American Museum of Natural History 145:119-218.

Prothero, D. R., and Rensberger, J. M. 1985. Preliminary magnetostratigraphy of the John Day Formation, Oregon, and the North American Oligocene-Miocene boundary. Newsletters on Stratigraphy 15:59-70.

Rasmussen, D. L. 1977. Geology and mammalian paleontology of the Oligocene-Miocene Cabbage Patch Formation, central-western Montana. Unpublished Ph.D. dissertation, University of Kansas, Lawrence, Kansas, 794 p.

Rensberger, J. M. 1971. Entoptychine pocket gophers (Mammalia, Geomyoidea) of the early Miocene John Day Formation, Oregon. University of California Publications in Geological Sciences 90:1-209.

______. 1973a. Pleurolicine rodents (Geomyoidea) of the John Day Formation, Oregon, and their relationships to taxa from the early and middle Miocene, South Dakota. University of California Publications in Geological Sciences 102:1-95.

______. 1973b. Sanctimus (Mammalia, Rodentia) and the phyletic relationships of the large Arikareean geomyoids. Journal of Paleontology 47:835-853.

______. 1979. Promylagaulus, progressive aplodontoid rodents of the early Miocene. Contributions in Science, Natural History Museum of Los Angeles County 312:1-18.

______. 1980. A primitive promylagauline rodent from the Sharps Formation, South Dakota. Journal of Paleontology 54:1267-1277.

______. 1983. Successions of meniscomyine and allomyine rodents (Aplodontidae) in the Oligo-Miocene John Day Formation, Oregon. University of California Publications in Geological Sciences 124:1-131.

Retallack, G. J. 1983. Late Eocene and Oligocene paleosols from the Badlands National Park, South Dakota. Geological Society of America Special Paper 193, 82 p.

Rich, T. H. V., and Rasmussen, D. L. 1973. New North American erinaceine hedgehogs (Mammalia:Insectivora). Occasional Papers, Museum of Natural History, University of Kansas 21:1-54.

Riggs, E. S. 1942. Some early Miocene carnivores. Field Museum of Natural History, Geological Series 9:69-114.

Rose, K. D., and Rensberger, J. M. 1983. Upper dentition of Ekgmowechashala (omomyid primate) from the John Day Formation, Oligo-Miocene of Oregon. Folia Primatolica 41:102-111.

Runkel, A. C. 1986. Geology and vertebrate paleontology of the Smith River Basin, Montana. Unpublished M.S. thesis, University of Montana, Missoula, Montana, 80 p.

Schlaikjer, E. M. 1935. Contributions to the stratigraphy and paleontology of the Goshen Hole area, Wyoming: Part 4, new vertebrates and the stratigraphy of the Oligocene and early Miocene. Bulletin of the Museum of Comparative Zoology, Harvard University 76:97-189.

Schultz, C. B., and Falkenbach, C. H. 1940. Merycochoerinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 72:213-306.

______., and ______. 1941. Ticholeptinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 79:1-105.

______., and ______. 1947. Merychyinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 88:157-286.

______., and ______. 1949. Promerycochoerinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 93:1-198.

______., and ______. 1950. Phenacocoelinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 95:87-150.

______., and ______. 1954. Desmatochoerinae, a new subfamily of oreodonts. Bulletin of the American Museum of Natural History 105:143-256.

______., and ______. 1968. The phylogeny of the oreodonts. Parts 1 and 2. Bulletin of the American Museum of Natural History 139:1-498.

Scott, W. B. 1893. The mammals of the Deep River beds. American Naturalist 27:659-662.

Seeland, D. 1985. Oligocene paleogeography of the northern Great Plains and adjacent mountains, p. 187-205. In Flores, R. M., and Kaplan, S. S. (eds.), Mountain Paleogeographic Symposium 3, Cenozoic paleogeography of west-central United States. Denver, Colorado, The Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists.

Simpson, G. G. 1960. Notes on the measurement of faunal resemblance. American Journal of Science, Bradley Volume, no. 258-A:300-311.

Skinner, M. F., Skinner, S. M., and Gooris, R. J. 1968. Cenozoic rocks and faunas of Turtle Butte, south-central South Dakota. Bulletin of the American Museum of Natural History 138:379-436.

Sneath, P. H. A., and Sokal, R. R. 1973. Numerical taxonomy. San Francisco, W. H. Freeman and Company., Publishers, 573 p.

Sokal, R. R., and Rohlf, F. J. 1962. The comparison of dendrograms by objective methods. Taxon 11:33-40.

Stirton, R. A. 1940. Phylogeny of North American Equidae. University of California Publications, Bulletin of the Department of Geological Sciences 25:165-198.

Stirton, R. A., and Rensberger, J. M. 1964. Occurrence of the insectivore genus Micropternodus in the John Day Formation of central Oregon. Bulletin of the Southern California Academy of Science 63:57-80.

SPSSx Inc. 1986. SPSSx user's guide, 2nd edition. New York, McGraw-Hill Book Company, 988 p.

Swinehart, J. B., Sounders, V. L., DeGraw, H. M., and Diffendal, R. F. 1985. Cenozoic paleogeography of western Nebraska, p. 209-230. In Flores, R. M., and Kaplan, S. S. (eds.), Rocky Mountain Paleogeographic Symposium 3, Cenozoic paleogeography of west-central United States. Denver, Colorado, The Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists.

Tedford, R. H., Galusha, T., Skinner, M. F., Taylor, B. E., Fields, R. W., MacDonald, J. R., Patton, T. H., Rensberger, J. M., and Whistler, D. P. In press. Faunal succession and biochronology of the Arikareean through Hemphillian interval (late Oligocene through late Miocene Epochs), North America. In Woodburne, M. O. (ed.), Vertebrate paleontology as a discipline in geochronology. Berkeley, University of California Press.

Thompson, G. T., Fields, R. W., and Alt, D. 1982. Land-based evidence of Tertiary climatic variations, northern Rockies. Geology 10:413-417.

Wahlert, J. H. 1976. Jimomys labaughi, a new geomyoid rodent from the early Barstovian of North America. American Museum Novitates 2591:1-6.

White, T. E. 1954. Preliminary analysis of the fossil vertebrates of the Canyon Ferry Reservoir area. Proceedings of the U.S. National Museum 103:395-438.

Wood, A. E. 1935. Evolution and relationships of the heteromyid rodents with new forms from the Tertiary of western North America. Annals of Carnegie Museum 24: 73-262.

______. 1936. Geomyid rodents from the middle Tertiary. American Museum Novitates 866:1-31.

Wood, A. E., and Konizeski, R. 1965. A new eutypomyid rodent from the Arikareean (Miocene) of Montana. Journal of Paleontology 39:492-496.

Woodburne, M. O. 1969. Systematics, biogeography, and evolution of Cynorca and Dyseohyus (Tayassuidae). Bulletin of the American Museum of Natural History 141:271-356.

Woodburne, M. O., Tedford, R. H., Stevens, M. S., and Taylor, B. E. 1974. Early Miocene mammalian faunas, Mojave desert, California. Journal of Paleontology 48:6-26.

APPENDIX A

The following is an example data file (p. 84-87) used in this study and its SPSSˣ output (p. 88-101). In the data files set up for this study, 1=the presence of a particular genus in a fauna and 0=the absence of a particular genus from a fauna. See SPSSˣ Inc. (1986) for more details.

```
FILE HANDLE EARIK.D/

DATA LIST FIXED RECORDS=1
  /TAXA 1-4 JD1 5 PC 6 CP 7 TR 8 MC 9 SR 10 GH 11 WR 12 WK1 13

SET LENGTH=NONE / WIDTH=80
FILE LABEL   EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA

VARIABLE LABELS
  JD1 'JOHN DAY FAUNA'
  PC 'PETERSON CREEK LOCAL FAUNA'
  CP 'CABBAGE PATCH FAUNA'
  TR 'TAVENNER RANCH LOCAL FAUNA'
  MC 'MAGPIE CREEK LOCAL FAUNA'
  SR 'SMITH RIVER FAUNA'
  GH 'GOSHEN HOLE FAUNA'
  WR 'WILDCAT RIDGE FAUNA'
  WK1 'WOUNDED KNEE FAUNA'

VALUE LABELS  TAXA 1 'GENUS'/

BEGIN DATA
005 101100011
010 001100010
015 000000010
020 001000011
025 000000001
030 001100011
035 000100000
040 001001001
045 000000011
050 100000000
055 000000010
060 000000010
065 011100011
070 001000001
075 001000000
080 001101011
085 000000001
090 000000001
095 101000011
100 100000011
105 001000001
110 010000000
115 011001111
120 101010001
125 000101111
```

130	000000001
135	001100000
140	000000011
145	001100011
150	111000001
155	101101011
160	100000000
165	011101001
170	100000000
175	100000000
180	001000000
185	000000011
190	010001001
195	000000001
200	100000001
205	100001000
210	000000010
215	000000010
220	100000000
225	110101111
230	001000110
235	001000011
240	100010011
245	000100000
250	001001000
255	001101110
260	001101001
265	101100001
270	001111001
275	000100011
280	000000011
285	000001011
290	100000000
295	110000001
300	000000111
305	100000011
310	000000011
315	000001011
320	101101011
325	111101011
330	000000101
335	000000011
340	000000010
345	001100011
350	000000011
355	000000111
360	101000101
365	100011011
370	000011011
375	000000001
380	000000011
385	100000010
390	000000011
395	100000001
400	000000001
405	100000000
410	100000000
415	000000001
420	100000000
425	100000011

```
430 010000000
435 100000001
440 000000001
445 100000010
450 000000010
455 100000011
460 100000001
465 100000000
470 100000001
475 111101111
480 000000100
485 100000110
490 000000111
495 100000000
500 000000001
505 101011011
510 000000110
515 100000000
520 000000001
525 100000000
530 100000000
535 100000011
540 000000111
545 100000000
550 000000001
555 010000001
560 001000000
565 100000001
570 100000001
575 101111000
580 010011111
585 100010010
590 100000000
595 011111111
600 101011111
605 100011100
610 100000000
615 000001010
620 100000000
625 100000000
630 100000000
635 100000000
640 000001111
645 000000010
650 000001111
655 000000111
660 000011101
665 000010111
670 000001111
675 100000101
680 100000000
685 000000110
690 000000000
695 000000111
700 100001000
705 000000011
710 001101000
715 000000010
END DATA
FILE HANDLE PROXJC/NAME='PROXJC.DAT'
```

```
PROCEDURE OUTPUT OUTFILE=PROXJC
PROXIMITIES  JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=JACCARD
  /WRITE
INPUT MATRIX FILE= PROXJC
CLUSTER  JD1 TO WK1
  /READ=SIMILAR
  /PLOT=DENDROGRAM

FILE HANDLE PROXK1/NAME='PROXK1.DAT'
PROCEDURE OUTPUT OUTFILE=PROXK1
PROXIMITIES JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=K1 RESCALE
  /WRITE
INPUT MATRIX FILE=PROXK1
CLUSTER JD1 TO WK1
  /READ=SIMILAR
  /PLOT=DENDROGRAM

FILE HANDLE PROXK2/NAME='PROXK2.DAT'
PROCEDURE OUTPUT OUTFILE=PROXK2
PROXIMITIES JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=K2
  /WRITE
INPUT MATRIX FILE=PROXK2
CLUSTER JD1 TO WK1
  /READ=SIMILAR
  /PLOT=DENDROGRAM

FILE HANDLE PPOXDC/NAME='PROXDC.DAT'
PROCEDURE OUTPUT OUTFILE=PROXDC
PROXIMITIES JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=DICE
  /WRITE
INPUT MATRIX FILE=PROXDC
CLUSTER JD1 TO WK1
  /READ=SIMILAR
  /PLOT=DENDROGRAM

FILE HANDLE PROXSM/NAME='PROXSM.DAT'
PROCEDURE OUTPUT OUTFILE=PROXSM
PROXIMITIES JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=SM
  /WRITE
INPUT MATRIX FILE=PROXSM
CLUSTER JD1 TO WK1
  /READ=SIMILAR
  /PLOT=DENDROGRAM
FINISH
```

```
 4-JUN-87    SPSS-X RELEASE 2.2+ FOR VAX/VMS
15:25:23     U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

For VMS V4.4             U of M  VAK/VMS  Node: UMT01      License Number 19451

********************************************************************************

                       NEW FEATURES IN SPSS-X RELEASE 2.2+

AUTORECODE - Recodes alpha and numeric values into consecutive integers and
     stores the new values in a different variable.

DROP DOCUMENTS - Allows you to remove documents from SPSS-X system files.

INCLUDE - Includes a file of SPSS-X commands in an SPSS-X job.

MANOVA - Has simplified syntax and output, and improved repeated measures tests.

RENAME VARIABLES - Changes the names of variables on the active file.

--------------------------------------------------------------------------------

                           SPSS-X ADD-ON OPTIONS

SPSS-X Capture for DATATRIEVE - Teams SPSS-X and DATATRIEVE to extend your data
     analysis and reporting capabilities.  It extracts DATATRIEVE information
     via the GET DATATRIEVE command.  The GET DATATRIEVE command is a major
     revision of the previous GET DATABASE DATATRIEVE command, but it also
     accepts the old command syntax.

SPSS-X Track for VAX/VMS - A collection of facilities designed to help system
     managers analyze accounting and system performance data gathered by the VMS
     ACCOUNTING, MONITOR, DISK QUOTA, AUTHORIZE, and ERROR LOG utilities.

SPSS-X TABLES - Produces customized tabulations suitable for presentation or
     publication.  Now allows statistics in banners and value labels in stubs.

LISREL - An advanced statistics program to analyze structural equation models.

--------------------------------------------------------------------------------

    For more information on these enhancements, use the SPSS-X INFO command.

********************************************************************************

    1  0
    2  0   FILE HANDLE EARIK.D/
    3  0
    4  0   DATA LIST FIXED RECORDS=1
    5  0     /TAXA 1-4 JD1 5 PC 6 CP 7 TR 8 MC 9 SR 10 GH 11 WR 12 WK1 13
    6  0

THE ABOVE DATA LIST STATEMENT WILL READ   1 RECORDS FROM FILE INLINE  .

          VARIABLE   REC  START    END          FORMAT  WIDTH  DEC
```

TAXA	1	1	4	F	4	0
JD1	1	5	5	F	1	0
PC	1	6	6	F	1	0
CP	1	7	7	F	1	0
TR	1	8	8	F	1	0
MC	1	9	9	F	1	0
SR	1	10	10	F	1	0
GH	1	11	11	F	1	0
WR	1	12	12	F	1	0
WK1	1	13	13	F	1	0

```
END OF DATALIST TABLE.

0  SET LENGTH=NONE / WIDTH=80
FILE LABEL   EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA

VARIABLE LABELS
  JD1 'JOHN DAY FAUNA'
  PC 'PETERSON CREEK LOCAL FAUNA'
  CP 'CABBAGE PATCH FAUNA'
  TR 'TAVENNER RANCH LOCAL FAUNA'
  MC 'MAGPIE CREEK LOCAL FAUNA'
  SR 'SMITH RIVER FAUNA'
  GH 'GOSHEN HOLE FAUNA'
  WR 'WILDCAT RIDGE FAUNA'
  WK1 'WOUNDED KNEE FAUNA'

VALUE LABELS  TAXA 1 'GENUS'/

BEGIN DATA


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                           PAGE   2
15:25:29  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4


PRECEDING TASK REQUIRED       0.31 SECONDS CPU TIME;       1.06 SECONDS ELAPSED.

FILE HANDLE PROXJC/NAME='PROXJC.DAT'
PROCEDURE OUTPUT OUTFILE=PROXJC
PROXIMITIES  JD1 TO WK1
  /VIEW=VARIABLE
  /MEASURE=JACCARD
  /WRITE

THERE ARE  2326224 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1860979 BYTES.
PROXIMITIES requires 10536 bytes of workspace for execution.


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                           PAGE   3
15:25:30  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4

FILE:      EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * * * * * * * * * P R O X I M I T I E S * * * * * * * * * * * * * *
```

Data Information

143 unweighted cases accepted.
0 cases rejected because of missing value.

Jaccard measure used.

- -

Jaccard Similarity Coefficient Matrix

Variable	JD1	PC	CP	TR	MC
PC	.0735				
CP	.1566	.1591			
TR	.1053	.1918	.4762		
MC	.1231	.0769	.1333	.0833	
SR	.1500	.2051	.3209	.3182	.2703
GH	.0875	.1351	.1207	.1042	.1667
WR	.1835	.0909	.2279	.2025	.1200
WK1	.2500	.1364	.2813	.1935	.1236

Variable	SR	GH	WR
GH	.2708		
WR	.2561	.2895	
WK1	.2660	.2253	.4857

- -

```
4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                  PAGE    4
15:25:32  U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

PRECEDING TASK REQUIRED       0.42 SECONDS CPU TIME;       4.01 SECONDS ELAPSED.

  30  INPUT MATRIX FILE= PROXJC
  31  CLUSTER  JD1 TO WK1
  32    /READ=SIMILAR
  33    /PLOT=DENDROGRAM
  34

THERE ARE  2326304 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1361043 BYTES.
CLUSTER requires 520 bytes of workspace for execution.


4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                  PAGE    5
15:25:33  U of M  VAX/VMS  Node: UMT01      DEC VAX-3600   VMS V4.4

FILE:     EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *
```

Data Information

A Rectangular (Similarity) Coefficient Matrix Read.

1 Agglomeration method specified.

- -

```
4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                   PAGE   6
15:25:33  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4
```

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	8	9	.485710	0	0	4
2	3	4	.476190	0	0	3
3	3	6	.319465	2	0	5
4	7	8	.257640	0	1	5
5	3	7	.213886	3	4	6
6	1	3	.155480	0	5	7
7	1	5	.145754	6	0	8
8	1	2	.132362	7	0	0

```
4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                   PAGE   7
15:25:34  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4
```

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Dendrogram using Average Linkage (Between Groups)

```
                          Rescaled Distance Cluster Combine

  C A S E         0         5        10        15        20        25
Label        Seq  +---------+---------+---------+---------+---------+

WR             8   -+-------------------------------+
WK1            9   -+                               +-----+
GH             7   ---------------------------------+     +-------+
CP             3   -+---------------------+               |       |
TR             4   -+                     +---------------+       +-+
SR             6   -----------------------+                       | |
JD1            1   -----------------------------------------------+ |
MC             5   -------------------------------------------------+
PC             2   -------------------------------------------------+
```

```
4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                   PAGE   8
15:25:34  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4
```

PRECEDING TASK REQUIRED   0.21 SECONDS CPU TIME;   1.36 SECONDS ELAPSED.

```
 35  FILE HANDLE PROXK1/NAME='PROXK1.DAT'
 36  PROCEDURE OUTPUT OUTFILE=PROXK1
 37  PROXIMITIES JD1 TO WK1
 38    /VIEW=VARIABLE
 39    /MEASURE=K1 RESCALE
 40    /WRITE

THERE ARE  2325608 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1860486 BYTES.
PROXIMITIES requires 10536 bytes of workspace for execution.


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE   9
15:25:34  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600    VMS V4.4

FILE:     EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * * * * * * * * * P R O X I M I T I E S * * * * * * * * * * * * * *
```

Data Information

143 unweighted cases accepted.
0 cases rejected because of missing value.

Rescaled Kulzynski 1 measure used.

- -

Rescaled Kulzynski 1 Similarity Coefficient Matrix

Variable	JD1	PC	CP	TR	MC
PC	.0000				
CP	.1229	.1270			
TR	.0443	.1651	.9591		
MC	.0705	.0046	.0861	.0133	
SR	.1123	.2066	.4541	.4477	.3364
GH	.0191	.0889	.0669	.0427	.1394
WR	.1680	.0239	.2533	.2018	.0659
WK1	.2936	.0908	.3606	.1857	.0713

Variable	SR	GH	WR
GH	.3376		
WR	.3062	.3792	
WK1	.3271	.2454	1.0000

- -

```
 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  10
15:25:35  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600    VMS V4.4

PRECEDING TASK REQUIRED      0.36 SECONDS CPU TIME;      1.38 SECONDS ELAPSED.

 41  INPUT MATRIX FILE=PROXK1
 42  CLUSTER JD1 TO WK1
```

```
43    /READ=SIMILAR
44    /PLOT=DENDROGRAM
45

THERE ARE  2326032 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1860325 BYTES.
CLUSTER requires 520 bytes of workspace for execution.


 4-JUN-97 SPSS-X RELEASE 2.2+ FOR VAX/VMS                              PAGE  11
15:25:36  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4

FILE:     EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Data   Information

   A Rectangular (Similarity) Coefficient Matrix Read.

 1 Agglomeration method specified.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


 4-JUN-97 SPSS-X RELEASE 2.2+ FOR VAX/VMS                              PAGE  12
15:25:36  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *


  Agglomeration Schedule using Average Linkage (Between Groups)
```

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	8	9	1.000000	0	0	4
2	3	4	.959130	0	0	3
3	3	6	.450920	2	0	5
4	7	8	.312305	0	1	5
5	3	7	.231324	3	4	6
6	1	3	.126690	0	5	7
7	1	5	.111850	6	0	8
8	1	2	.088345	7	0	0

```
 4-JUN-97 SPSS-X RELEASE 2.2+ FOR VAX/VMS                              PAGE  13
15:25:36  U of M  VAX/VMS  Node: UMT01     DEC VAX-8600   VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *


 Dendrogram using Average Linkage (Between Groups)

                         Rescaled Distance Cluster Combine

    C A S E      0         5         10        15        20        25
```

```
Label      Seq   +---------+---------+---------+---------+---------+

WR           8   -+-------------------------------------+
WK1          9   -+                                     +------+
GH           7   --------------------------------------+      +---+
CP           3   ---+-------------------------------+          |   |
TR           4   ---+                               +------------+   +-+
SR           6   -------------------------------+                    | |
JO1          1   ----------------------------------------------------+ |
MC           5   ------------------------------------------------------+
PC           2   ------------------------------------------------------+
```

```
 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  14
15:25:36  U of M   VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

PRECEDING TASK REQUIRED        0.19 SECONDS CPU TIME;        0.64 SECONDS ELAPSED.

  46   FILE HANDLE PROXK2/NAME='PROXK2.DAT'
  47   PROCEDURE OUTPUT OUTFILE=PROXK2
  48   PROXIMITIES JO1 TO WK1
  49     /VIEW=VARIABLE
  50     /MEASURE=K2
  51     /WRITE

THERE ARE  2325384 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1860307 BYTES.
PROXIMITIES requires 10536 bytes of workspace for execution.
```

```
 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  15
15:25:37  U of M   VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

FILE:      EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * * * * * * * * * * P R O X I M I T I E S * * * * * * * * * * * * * * *
```

Data Information

143 unweighted cases accepted.
0 cases rejected because of missing value.

Kulzynski 2 measure used.

- -

Kulzynski 2 Similarity Coefficient Matrix

Variable	JO1	PC	CP	TR	MC
PC	.2209				
CP	.2859	.3446			
TR	.2273	.3343	.6703		
MC	.3533	.1429	.2954	.1571	
SR	.2335	.4069	.4873	.4921	.508
GH	.1343	.2679	.2196	.1393	.321
WR	.3123	.3000	.4131	.4343	.395

WK1	.4144	.4983	.5218	.4647	.4568

Variable	SR	GH	WR
GH	.4291		
WR	.4682	.5500	
WK1	.5241	.4971	.6608

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 16
15:25:37 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

PRECEDING TASK REQUIRED 0.30 SECONDS CPU TIME; 0.77 SECONDS ELAPSED.

```
52  INPUT MATRIX FILE=PROXK2
53  CLUSTER JD1 TO WK1
54    /READ=SIMILAR
55    /PLOT=DENDROGRAM
56
```

THERE ARE 2325760 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 1860608 BYTES.
CLUSTER requires 520 bytes of workspace for execution.

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 17
15:25:38 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

FILE: EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * * *

Data Information

A Rectangular (Similarity) Coefficient Matrix Read.

1 Agglomeration method specified.

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 18
15:25:38 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * * *

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	3	4	.670270	0	0	6
2	8	9	.660800	0	0	3

3	7	8	.523545	0	2	5
4	5	6	.508660	0	0	5
5	5	7	.430897	4	3	6
6	3	5	.368473	1	5	7
7	2	3	.327839	0	6	8
8	1	2	.285331	0	7	0

```
 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  19
15:25:38  U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

 Dendrogram using Average Linkage (Between Groups)

                          Rescaled Distance Cluster Combine

    C A S E       0         5        10        15        20        25
  Label     Seq   +---------+---------+---------+---------+---------+

  CP          3    -+-----------------------------------------+
  TR          4    -+                                         |
  WR          8    -+-----------------+                       +-----+
  WK1         9    -+                 +-----------+           |     |
  GH          7    -------------------+           +-------+   |     +---+
  MC          5    ---------------------+---------+           |     |   |
  SR          6    ---------------------+                     |     |   |
  PC          2    -----------------------------------------------+     |
  JD1         1    -----------------------------------------------------+


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  20
15:25:38  U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

PRECEDING TASK REQUIRED      0.20 SECONDS CPU TIME;      0.42 SECONDS ELAPSED.

  57  FILE HANDLE PROXDC/NAME='PROXDC.DAT'
  58  PROCEDURE OUTPUT OUTFILE=PROXDC
  59  PROXIMITIES JD1 TO WK1
  60    /VIEW=VARIABLE
  61    /MEASURE=DICE
  62    /WRITE

THERE ARE  2325112 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS  1850089 BYTES.
PROXIMITIES requires 10536 bytes of workspace for execution.


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                                PAGE  21
15:25:38  U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

FILE:     EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * * * * * * * * * P R O X I M I T I E S * * * * * * * * * * * * * *
```

Data Information

143 unweighted cases accepted.
0 cases rejected because of missing value.

Dice measure used.

- -

Dice Similarity Coefficient Matrix

Variable	JD1	PC	CP	TR	MC
PC	.1370				
CP	.2708	.2745			
TR	.1905	.3077	.6452		
MC	.2192	.1429	.2353	.1538	
SR	.2609	.3404	.4857	.4828	.4255
GH	.1609	.2381	.2154	.1887	.2857
WR	.3101	.1567	.3738	.3368	.2143
WK1	.4000	.2400	.4390	.3243	.2200

Variable	SR	GH	WR
GH	.4262		
WR	.4078	.4490	
WK1	.4202	.3684	.6538

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 22
15:25:39 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

PRECEDING TASK REQUIRED 0.34 SECONDS CPU TIME; 0.82 SECONDS ELAPSED.

```
63  INPUT MATRIX FILE=PROXDC
64  CLUSTER JD1 TO WK1
65    /READ=SIMILAR
66    /PLOT=DENDROGRAM
67
```

THERE ARE 2325488 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 1860390 BYTES.
CLUSTER requires 520 bytes of workspace for execution.

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 23
15:25:39 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

FILE: EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * H I E R A R C H I C A L C L U S T E R A N A L Y S I S * * * * * *

Data Information

A Rectangular (Similarity) Coefficient Matrix Read.

1 Agglomeration method specified.

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 24
15:25:39 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	8	9	.653850	0	0	4
2	3	4	.645160	0	0	3
3	3	6	.484235	2	0	5
4	7	8	.408700	0	1	5
5	3	7	.348027	3	4	6
6	1	3	.265530	0	5	7
7	1	5	.250550	6	0	8
8	1	2	.230906	7	0	0

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 25
15:25:39 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Dendrogram using Average Linkage (Between Groups)

```
                           Rescaled Distance Cluster Combine

  C A S E        0         5        10        15        20        25
  Label     Seq  +---------+---------+---------+---------+---------+

  WR          8   -+---------------------------+
  WK1         9   -+                           +---------+
  GM          7   -----------------------------+         +-------+
  CP          3   -+---------------------+               |       |
  TR          4   -+                     +---------------+       +-+
  SR          6   -----------------------+                       | +-+
  JD1         1   -----------------------------------------------+ | |
  MC          5   -------------------------------------------------+ |
  PC          2   ---------------------------------------------------+
```

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 26
15:25:39 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

PRECEDING TASK REQUIRED 0.18 SECONDS CPU TIME; 0.56 SECONDS ELAPSED.

```
68  FILE HANDLE PROXSM/NAME='PROXSM.DAT'
69  PROCEDURE OUTPUT OUTFILE=PROXSM
70  PROXIMITIES JD1 TO WK1
71    /VIEW=VARIABLE
72    /MEASURE=SM
73    /WRITE
```

THERE ARE 2324840 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 1859872 BYTES.
PROXIMITIES requires 10536 bytes of workspace for execution.

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 27
15:25:40 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

FILE: EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
* * * * * * * * * * * * * * P R O X I M I T I E S * * * * * * * * * * * * * *

Data Information

143 unweighted cases accepted.
0 cases rejected because of missing value.

Simple matching measure used.

- -

Simple matching Similarity Coefficient Matrix

Variable	JD1	PC	CP	TR	MC
PC	.5594				
CP	.5105	.7413			
TR	.5245	.8112	.8462		
MC	.6014	.8322	.7273	.7692	
SR	.5245	.7832	.7483	.7902	.8112
GH	.4895	.7762	.6434	.6993	.7902
WR	.3776	.5105	.5315	.5594	.5385
WK1	.3916	.4685	.5175	.4755	.4545

Variable	SR	GH	WR
GH	.7552		
WR	.5734	.6224	
WK1	.5175	.4965	.6224

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 28
15:25:40 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

PRECEDING TASK REQUIRED 0.29 SECONDS CPU TIME; 1.11 SECONDS ELAPSED.

```
74  INPUT MATRIX FILE=PROXSM
75  CLUSTER JD1 TO WK1
```

```
76    /READ=SIMILAR
77    /PLOT=DENDROGRAM
```

THERE ARE 2325216 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 1860172 BYTES.
CLUSTER requires 520 bytes of workspace for execution.

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 29
15:25:41 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

FILE: EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Data Information

A Rectangular (Similarity) Coefficient Matrix Read.

1 Agglomeration method specified.

- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 30
15:25:41 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	3	4	.846150	0	0	5
2	2	5	.832170	0	0	3
3	2	6	.797205	2	0	4
4	2	7	.773890	3	0	5
5	2	3	.741259	4	1	7
6	8	9	.622330	0	0	8
7	1	2	.534967	0	5	8
8	1	8	.502497	7	6	0

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 31
15:25:41 U of M VAX/VMS Node: UMTO1 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Dendrogram using Average Linkage (Between Groups)

```
                          Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
 Label     Seq  +---------+---------+---------+---------+---------+
```

```
CP          3   -+-------------+
TR          4   -+             |
PC          2   ---+---+       +----------------------------+
MC          5   ---+   +---+   |                            |
SR          6   -------+   +---+                            +---+
GH          7   -----------+                                |   |
JD1         1   --------------------------------------------+   |
WR          8   --------------------------------+---------------+
VK1         9   --------------------------------+


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                              PAGE  32
15:25:41   U of M   VAX/VMS   Node: UMT01      DEC VAX-8600   VMS V4.4

PRECEDING TASK REQUIRED       0.22 SECONDS CPU TIME;       0.71 SECONDS ELAPSED.

  78  FINISH

           78 COMMAND LINES READ.
            0 ERRORS DETECTED.
            0 WARNINGS ISSUED.
            4 SECONDS CPU TIME.
           21 SECONDS ELAPSED TIME.
              END OF JOB.
```

APPENDIX A (CONTINUED)

The following is an example data file set up to cluster Simpson coefficient values (p. 102) and its SPSSx output (p. 103-105). See SPSSx Inc. (1986) for more details.

```
file handle earik.d/
data list  fixed records=1
    /JD 4-9 PC 11-16 CP 18-23 TR 25-30 CF 32-37 SR 39-44
            GH 46-51 WR 53-58 WK 60-65
set length=none / width=80
file label   EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
variable labels     JD 'John Day Fauna'
                    PC 'Peterson Creek local fauna'
                    CP 'Cabbage Patch Fauna'
                    TR 'Tavenner Ranch local fauna'
                    CF 'Magpie Creek local fauna'
                    SR 'Smith River Fauna'
                    GH 'Goshen Hole Fauna'
                    WR 'Wildcat Ridge Fauna'
                    WK 'Wounded Knee Fauna'
input program
numeric JD PC CP TR CF SR GH WR WK
input matrix free
end input program
cluster JD to WK
  /read=similar
  /print=schedule
  /plot=dendrogram
begin data
   1.0000 0.3571 0.3514 0.3200 0.5714 0.3636 0.2500 0.3390 0.4915
   0.3571 1.0000 0.5000 0.4286 0.1429 0.5714 0.3571 0.5000 0.8571
   0.3514 0.5000 1.0000 0.8000 0.4286 0.5152 0.2500 0.5405 0.7297
   0.3200 0.4286 0.8000 1.0000 0.2143 0.5600 0.2000 0.6400 0.7200
   0.5714 0.1429 0.4286 0.2143 1.0000 0.7143 0.4286 0.6429 0.7857
   0.3636 0.5714 0.5152 0.5600 0.7143 1.0000 0.4643 0.6364 0.7813
   0.2500 0.3571 0.2500 0.2000 0.4286 0.4643 1.0000 0.7857 0.7500
   0.3390 0.5000 0.5405 0.6400 0.6429 0.6364 0.7857 1.0000 0.7286
   0.4915 0.3571 0.7297 0.7200 0.7857 0.7813 0.7500 0.7286 1.0000
end data
finish
```

```
 4-JUN-97   SPSS-X RELEASE 2.2+ FOR VAX/VMS
15:34:36    U of M  VAX/VMS  Node: UMT01      DEC VAX-8600   VMS V4.4

For VMS V4.4              U of M  VAX/VMS  Node: UMT01      License Number 19451
********************************************************************************
                        NEW FEATURES IN SPSS-X RELEASE 2.2+

AUTORECODE - Recodes alpha and numeric values into consecutive integers and
     stores the new values in a different variable.

DROP DOCUMENTS - Allows you to remove documents from SPSS-X system files.

INCLUDE - Includes a file of SPSS-X commands in an SPSS-X job.

MANOVA - Has simplified syntax and output, and improved repeated measures tests.

RENAME VARIABLES - Changes the names of variables on the active file.
--------------------------------------------------------------------------------
                              SPSS-X ADD-ON OPTIONS

SPSS-X Capture for DATATRIEVE - Teams SPSS-X and DATATRIEVE to extend your data
     analysis and reporting capabilities.  It extracts DATATRIEVE information
     via the GET DATATRIEVE command.  The GET DATATRIEVE command is a major
     revision of the previous GET DATABASE DATATRIEVE command, but it also
     accepts the old command syntax.

SPSS-X Track for VAX/VMS - A collection of facilities designed to help system
     managers analyze accounting and system performance data gathered by the VMS
     ACCOUNTING, MONITOR, DISK QUOTA, AUTHORIZE, and ERROR LOG utilities.

SPSS-X TABLES - Produces customized tabulations suitable for presentation or
     publication.  Now allows statistics in banners and value labels in stubs.

LISREL - An advanced statistics program to analyze structural equation models.
--------------------------------------------------------------------------------
    For more information on these enhancements, use the SPSS-X INFO command.
********************************************************************************
   1  0  file handle earik.d/
   2  0  data list  fixed records=1
   3  0      /JD 4-9 PC 11-16 CP 18-23 TR 25-30 CF 32-37 SR 39-44
   4  0               GH 46-51 WR 53-58 JK 60-65

THE ABOVE DATA LIST STATEMENT WILL READ   1 RECORDS FROM FILE INLINE  .

        VARIABLE   REC  START    END         FORMAT  WIDTH  DEC

        JD          1      4      9          F          6    0
        PC          1     11     16          F          6    0
```

CP	1	18	23	F	6	0
TR	1	25	30	F	6	0
CF	1	32	37	F	6	0
SR	1	39	44	F	6	0
GH	1	46	51	F	6	0
WR	1	53	58	F	6	0
WK	1	60	65	F	6	0

END OF DATALIST TABLE.

```
  5  0  set length=none / width=80
  6  file label    EARLY ARIKAREEAN SIMILARITY COEFFICIENT DATA
  7  variable labels     JD 'John Day Fauna'
  8                      PC 'Peterson Creek local fauna'
  9                      CP 'Cabbage Patch Fauna'
 10                      TR 'Tavenner Ranch local fauna'
 11                      CF 'Magpie Creek local fauna'
 12                      SR 'Smith River Fauna'
 13                      GH 'Goshen Hole Fauna'
 14                      WR 'Wildcat Ridge Fauna'
 15                      WK 'Wounded Knee Fauna'
 16  input program
 17  numeric JD PC CP TR CF SR GH WR WK
 18  input matrix free
 19  end input program
 20  cluster JD to WK
 21    /read=similar
 22    /print=schedule
 23    /plot=dendrogram
```

THERE ARE 2326472 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 1961177 BYTES.
CLUSTER requires 520 bytes of workspace for execution.

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 2
15:34:39 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Data Information

A Rectangular (Similarity) Coefficient Matrix Read.

1 Agglomeration method specified.

\- -

4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS PAGE 3
15:34:39 U of M VAX/VMS Node: UMT01 DEC VAX-8600 VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined Cluster 1	Cluster 2	Coefficient	Stage Cluster 1st Appears Cluster 1	Cluster 2	Next Stage
1	2	9	.857100	0	0	5
2	3	4	.800000	0	0	5
3	7	8	.785700	0	0	6
4	5	6	.714300	0	0	6
5	2	3	.594575	1	2	7
6	5	7	.543050	4	3	7
7	2	5	.497850	5	6	8
8	1	2	.380500	0	7	0

```
 4-JUN-37 SPSS-X RELEASE 2.2+ FOR VAX/VMS                          PAGE   4
15:34:39  U of M  VAX/VMS  Node: UMT01    DEC VAX-8600   VMS V4.4

* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

 Dendrogram using Average Linkage (Between Groups)

                         Rescaled Distance Cluster Combine

    C A S E      0         5        10        15        20        25
  Label     Seq  +---------+---------+---------+---------+---------+

  PC          2   -+-------------------------+
  WK          9   -+                         +----------+
  CP          3   -----+---------------------+          |
  TR          4   -----+                                +-----------+
  GH          7   -------+-------------------------+    |           |
  WR          8   -------+                         +----+           |
  CF          5   ---------------+-----------------+                |
  SR          6   ---------------+                                  |
  JD          1   --------------------------------------------------+


 4-JUN-87 SPSS-X RELEASE 2.2+ FOR VAX/VMS                          PAGE   5
15:34:39  U of M  VAX/VMS  Node: UMT01    DEC VAX-8600   VMS V4.4

PRECEDING TASK REQUIRED      0.24 SECONDS CPU TIME;      1.12 SECONDS ELAPSED.

  25  finish

           25 COMMAND LINES READ.
            0 ERRORS DETECTED.
            0 WARNINGS ISSUED.
            1 SECONDS CPU TIME.
            5 SECONDS ELAPSED TIME.
              END OF JOB.
```